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Papers on Hydraulic Engineering. By SAMUEL MCELROY, C. E.

(Continued from p. 150.)

No. 2.—DISTRIBUTION—(Continued).

Tuberculation.—In addition to the ordinary process of oxidation to which iron is subject, cast iron water pipes are peculiarly liable to the production of internal accretions or tubercles, which restrict their calibre and discharge, and involve a chemical action destructive to the metal.

Of these evils, the former is the most important, since the gradual or partial loss of section, by irregular accretions, exerts an influence on the immediate usefulness of the pipes, which exceeds any question of cost in eventual replacement.

We have had frequent occasion to notice the rapid destruction of wrought iron produced by sea water, in which particular veins and portions of the iron are the most rapidly injured, showing that the relative constituents of the special forging exposed determine the rapidity of this action; and from frequent observation of like action on cast iron water pipes by fresh water, it is plain that this chemical process, though less formidable in degree in this case, is attributable to the same laws.

We are informed that in the mining pumps of the Pennsylvania coal region, it is not uncommon to have the lower pipes entirely de-

stroyed in process of time by a change into plumbago, from water action, and instances are on record in water works experience, where the entire castings of the mains have been gradually transformed, retaining the form, but completely altering the substance, in certain local cases.

Observations were recorded in the *Edinburgh Philosophical Journal* in 1822, by Dr. J. Macculloch, on the production of black lead from cast iron, under experiments with sea water, porter, acids, &c., which have been recently extended by Dr. Crace Calvert, as noticed in the *London Engineer* of January, 1862, demonstrating the formation of plumbago from cubes of cast iron.

From 1838 to 1843, in England, Mr. Robert Mallet made investigations of the operation of water on iron, in reference to water pipes, of which the results are thus stated to the British Association for the Advancement of Science:—

"He found that any sort of iron, cast or wrought, corrodes when exposed to the action of water holding air in combination, in one or other, or some combination of the following forms, viz: 1. *Uniformly*, or when the whole surface of the iron is covered uniformly with a coat of rust, requiring to be scraped off, and leaving a smooth, red surface after it. 2. *Uniformly, with plumbago*, where the surface, as being uniformly corroded, is found in some places covered with plumbagenous matter, leaving a piebald surface of red and black upon it. 3. *Locally*, or only rusted in some places, and free from rust in others. 4. *Locally pitted*, where the surface is left as in the last case, but the metal is found unequally removed to a greater or less depth. 5. *Tubercular*, where the whole of the rust which has taken place at every point of the specimen, has been transferred to one or more particular points of its surface, and has there formed large projecting tubercles, leaving the rest bare."

"The great elements of difference of corrosion as respects the iron itself appear to be:—

"1. The degree of *homogeneity* of substance of the metal, and especially of its surface.

"2. The degree of *density* of the metal, and state of its crystalline arrangement.

"3. The amount of *uncombined carbon* or suspended *graphite* contained in the iron;

"And therefore, that the more homogeneous,—the denser, harder, and closer grained, and the less graphitic,—the smaller is the index of corrosion."

From examinations of the Cochituate mains, made by Prof. Horsford in 1853, he expressed the opinion that—

"There has been *galvanic action*, arising in one class of cases from the contact of metals of unlike affinity for oxygen, and generally from a *want of homogeneity* of the iron; and to this, more than any other agency, is to be ascribed the rapid formation of accretions."—*Cochituate Water Report*, Jan., 1853.

While the law of this action is universal, and its effects are always to be anticipated, the degree of action is modified by the special conditions of any particular system of mains. Quality of water, rapidity of flow, temperature, and other circumstances, in connexion with the special quality of the castings exposed, may accelerate or retard these formations; and our information as to their existence and effects, however well established as to the law, is somewhat defective in special records, partly because the action is hidden from sight, and partly

because, when exposed, it is customary with water works administrations to conceal or deny the existence of defects.

Some of these effects may be thus briefly noticed:—

It was observed at *Grenoble*, in France, that the cast iron feed-main had reduced its flow on this account, between 1826 and 1833, from 370 to 190 wine gallons per minute.

It was noticed at *Cherbourg*, that from 1836 and 1838 to 1850, the effective section of the supply main had been reduced to less than one-third its original calibre, the accretions being 1·575 to 1·968 inches in height.

In the reports of the water works in England, numerous instances are recorded of the effects of tuberculation, which are also prominently noticed in locomotive boilers, and other kinds of exposed iron work.

In 1852, Mr. E. S. Chesbrough, Engineer of the Cochituate Board, Boston, reports that—

"The rapidity with which the interior surfaces of some of the pipes have been covered with tubercles or rust, has excited a great deal of interest. * * * All the large pipes that have been opened have been partially or entirely covered on their inner surfaces, some with detached tubercles varying from a half to two and a half inches base, with a depth or thickness in the middle of from one-quarter to three-quarters of an inch; and some entirely to an average depth of half an inch, with a rough coating, as if the bases of the tubercles had crowded together. The smaller pipes all exhibit some action of this kind, but generally to a less extent as regards thickness than the larger ones. In one case, however, a 4-inch pipe was found covered to a thickness of about one inch."

In 1853, the Cochituate Board remarks—

"The extent to which these accretions have affected the discharge of water from the pipes, by diminishing their area, and increasing the friction, has been satisfactorily ascertained by observations made by the City Engineer, with great care, on one of the 30-inch mains across Charles River, and is found to be much greater than was anticipated. The loss of discharge under the common head of six inches was found to be upwards of twenty per cent. of the known discharge of a new main of like diameter. Similar observations on the 30-inch main from the Brooklyn Reservoir, under the ordinary head of eight feet, gave the same result."

This action at Boston was very carefully recorded for a time, demonstrating a very serious injury to the whole distribution system. The Board, however, seems to have consoled itself at last with the theory that the action exhausted itself at a certain stage, and continues to extend the service with cast iron pipes.

The effective diameter of the 20-inch main of the Jersey City Water Works, recently examined, was found to be less than 18 inches.

Considerable reduction from tubercles is recorded on the Croton mains and smaller pipes.

From the action of the water on the pump valves and other engine castings of the Brooklyn pumping engines, the discoloration of the water at fires, and other evidences, this action is serious on the unprotected Brooklyn distribution.

Similar effects are recorded in various other water works of the

United States, in confirmation of what may be properly assumed as a law of chemical action, more or less powerful, in special localities.

Preventives.—Various efforts have been made to apply washes, paints, and varnishes, by different processes, so as to prevent contact between the water and iron, in castings as well as wrought iron work. A galvanic action has also been provided by coatings of zinc and other metals, and various enamelling processes have been invented.

Among these may be mentioned white-wash of pure lime, a wash of hydraulic cement, linseed oil applied under pressure, a composition of oil and wax, copal and other varnishes, lead and zinc paints, and coal tar varnish or paint.

And of all these, including galvanism and enamelling, experience goes to show that they have various special merits as palliatives, but no permanent power as preventives. Paints of all classes need periodical renewal; varnishes and enamels sooner or later peel off or wear off; and galvanism simply delays by destruction in one direction the eventual process of destruction in another. To make either palliative effectual, even for a time, requires careful and expensive workmanship, and the point of final failure is merely a question of time, which question should properly determine the propriety of its use, in connexion with the relative cost of use, in those cases where want of access prevents renewals.

On large dry-dock gates and caissons of wrought iron, exposed to sea water, without excessive motion, we have found a body-coat of red lead, with super-coats of zinc paint, the most durable and satisfactory; while for the iron work of steamer water-wheels and other parts much exposed, coal tar paint, though requiring frequent renewals, is more easily applied, and probably more effectual. Various experiments which have been made with coal tar varnish in contrast with other coatings, seem to favor it strongly when applied to a hot and clean surface, although its advocates admit its defects when not thus applied. Hence this process has been adopted in several water-supplies in England, and is being introduced into this country to a considerable extent. The large mains at Brooklyn, with those now used for extensions, and the 5-feet mains of the Croton extension, are thus coated. Other water works are following this example, all the pipes required for the Charlestown Water Works, now going under contract, being specified with this protective, in case cast iron pipes are used at all.

As now applied in this process, the pipes are dipped in a varnish-bath maintained at a temperature of 300°, when first cast, or are oiled to prevent rust, until they can be coated. The additional cost is about $1·25 to $1·50 per ton. The pipes being laid, renewals in coating are prevented, and its duration will vary with circumstances, being in some cases a matter of years, in others, of months and weeks. Of the mains coated by Dr. Smith's process at Glasgow, for the Brooklyn works, many of those exposed in the pipe-yard for a few months lost their varnish from the effects of the weather, while others remained in good condition, and all the coatings hitherto applied can only be regarded as palliatives.

While it is fixed and certain, that no engineer is justified in laying unprotected cast iron pipe, the protections themselves require careful study, and the most faithful application.

Wrought Iron Cement Pipe.—Among other substitutes which have been adopted for water pipes, those of wrought iron riveted in proper lengths, and lined and coated with a thick body of hydraulic cement mortar, have been very extensively used in this country, within the past fifteen years. The several lengths are put together by butt joints secured by sleeves, filled in with cement to prevent leakage, or by cast iron hubs protected by mortar from contact with the water. The pipes by one process in use, are lined with mortar applied under strong pressure, and coated when laid in the trench; and by another process they are both lined and coated under pressure at one operation. In one case the taps are inserted by brazing a tap plate and tap to the outer iron shell before the drill is used; and in another, by the use of cast iron rings tapped as in ordinary cast pipe.

Without discussing the merits of the several patents which apply to details of manufacture, it is manifest that the pipes themselves embody an important principle of durability, by the preservative effect of cement on iron, which excludes air and prevents oxidation and tuberculation, and which continues to increase in solidity and strength with increased age. It is also manifest that any desirable measure of strength may be attained by regulating the quality and thickness of the iron body. The cement lining is not less than one half inch thick for the smaller diameters of three and four inches, and by pressure is very firmly set to the iron plate.

Pipes of this kind can be manufactured and laid with less cost than those of cast iron, and have several valuable qualifications, when properly put down.

Lead Service Pipe.—The use of lead for house service from the street mains, although a matter of common practice, has given rise to elaborate investigations and discussions in Europe and in this country. This use has obtained against the serious objections urged against the material, on account of its ductility, its strength, and its sources of profit to plumbers, and some disadvantages in manufacture or use of its occasional substitutes. In some cities, however, as at Hartford, it is directly prohibited.

From the investigations on this subject at Boston in 1848, about the time of introducing the Cochituate supply, it was determined to admit its use. While all the experiments showed that lead is dissolved by water, it was argued that the Cochituate was not more dangerous in this action than the Croton, and that "a coat forms on the lead, which, for all practical purposes, becomes, in process of time, impermeable to, and insoluble in, the water in which it occurs." And this sums up all the chemical discussion in its favor, viz: that the quantity dissolved is insignificant, and that the process is self-protective in time.

It is plain, however, from an examination of the varied analyses and discussions of this matter, that the defence is apologetic at the best;

while on the other hand, the doctrine of cumulative effects, the voluminous testimony as to lead diseases, the extensive prevalence of those which may be directly or indirectly attributed to the effects of lead, as colics, paralyses, neuralgia, rheumatism, &c., and the proof that at Boston and in other localities the coating is not a protective, certainly justify a distrust of this claim of immunity, and a general rejection of the material. To furnish an adequate and safe substitute certainly need not overtax engineering skill.

Appurtenances.—Of these, stop-cocks and hydrants are the most important; the former being used to district the supply for convenience of repairs and access, and the latter for fire purposes, street washing, and other public uses.

Among the various forms of stop-cocks in use, probably the best are those which are built with a globular head acting in part as an air chamber, and with a flaring groove for the gate. In the first case, greater strength is secured in a limited space; and in the second, the gates are prevented from jamming, as the larger ones are apt to do with too narrow a groove, in working one brass face against another. Face joints are also preferable to lead joints, in obviating the necessity of caulking. Much inconvenience is often caused by improper arrangement of the stop-cock districts, where long distances are attempted to be controlled to save expense in original construction, and it is desirable to condense these districts of control as much as possible.

The ordinary form of fire hydrant in use, as to the tube itself, and not as to its case, seems to have been adopted from one city to another, with very little regard to its purpose of operation. The range of ingenuity seems to have rested content with the automatic vent which drains the tube above the valve when not in use, to prevent frost. In the ordinary tube the valve is operated within, by a rod passing through a stuffing-box in the tube-head, which raises and lowers it, to close or open the hydrant. Generally, a four-inch hydrant main is attached to a three-inch vertical tube, with a two-and-a-half-inch nozzle, and the effective section of the hydrant is less than one-half the section of the branch main. Hence it follows that in consequence of excessive hydrant friction, the supply of a street main, six inches in diameter, cannot feed more than two fire engines on the same block, through two hydrants, and our steam fire engines are obliged to put a suction on the hydrant nozzle to get their supply at all.

Now it is evident that if there is any propriety in using four-inch branches, there is none in using hydrants throttled down by rude, internal working parts to effective sections of less than one-half the branch calibre, and with the universal introduction of steam fire engines, all the present system of branches and hydrants must be improved. There is no mechanical difficulty whatever in making hydrant tubes with a free delivery equal to that of the branch, and this should always be done.

In all cases where steam fire engines are provided for, the hydrant nozzles may be adapted by the use of a double nozzle, either to the ordinary hose connexion, or a steamer connexion of the full hydrant

size; but the best way to arrange them is to make a full size hydrant nozzle, using a set of reducers for ordinary fire hose. Instances abound in the experience of firemen, where most valuable property has been lost, solely on account of the excessive friction of hydrants, where time prevented the intervention of engines.

The use of iron cases, both for hydrants and stop-cocks, is an improvement on the ordinary wooden boxes, which should be made universal, as a matter of economy, science, and ornament.

The following table will illustrate the relation of appurtenances to mains adopted in the case of a single prominent supply.

Aggregate Boston Distribution, January 1, 1862.

Diameters (inches), .	40	36 .	30	24	20	16	12	6	4	Total.
Length of Pipes (feet),	23·082	21·065	31·836	5·773	24·127	7·619	90·625	384·480	104·633	693 240
Stop-cocks, . .	4	5	8	10	11	22	163	682	283	1·188
Hydrants, . .										1·451

On this work all the wooden boxes which are replaced are Burnetized to prevent decay.

In this rapid sketch, in which the discussion of details is not admissible, we present, as to Distribution, some of those prominent features which directly affect its cost, durability, and usefulness, and which involve systems of practice more or less common, and, in some cases objectionable, with the hope that inventive genius, prompted by general assent, may mark out the most feasible and satisfactory correctives for our adoption.

(To be Continued.)

On some recently executed Deep Wells and Borings. By GEORGE R. BURNELL, C.E., F.G.S., F.S.A. Read before the Society of Arts.

From the Civ. Eng. and Arch. Jour., March, 1862.

The remarkable success of the operations carried on at Passy, for the supply of the artificial waters of the Bois de Boulogne by means of an artesian boring of unusually large diameter, has lately revived the public interest in that class of operations, both on the continent and in England. It has been proposed, indeed, to apply that system, on even a larger scale than was tried at Paris, to our own metropolis; and the scheme for sinking a series of deep wells in the various parts of London has been revived by some enthusiastic admirers of the results obtained by our neighbors. Experience has already decided the problem of the possible success of such attempts here, and it may, therefore, be desirable at the present day to review briefly the history of artesian wells at home and abroad, in order to prevent the waste of money, and the disappointment which may arise from ill-advised imitation of the measures proved to be successful in some cases, but by no means universally applicable.

The term "artesian well" means, strictly speaking, only a well sunk to a considerable depth, through a dry and impermeable upper stra-

tum, to a lower stratum charged with water, under such conditions of pressure as to cause the water to flow over the surface of the ground. The first wells of this description mentioned in modern works on hydraulics were executed in the province of the Artois, in France, where they were sunk in the chalk formation, and were supplied by the streams running between the fissures of that deposit, which were fed by the infiltration from the higher ground of the great north-eastern chalk plateau of France. It is said that some of these wells in the Artois have been used for nearly a thousand years, without any perceptible diminution in their supply; but it must also be added that the ancient Egyptians and the Chinese had, from the remotest antiquity, been acquainted with this method of obtaining water, and that the inhabitants of the plains of Lombardy have long used the waters rising from the deep-seated strata of the valley of the Po for the irrigation of their "marcite," or winter meadows. Be this as it may, and without dwelling upon the locality where this description of well was first made, it seems that about the beginning of the present century great attention was drawn to them by the success of a number of borings through the London clay into the sands of the basement beds of that formation, made in the valleys of the Lea, near Broxbourne, Waltham, and Tottenham, and of the Wondle, near Mitcham, Garratt, Wandsworth, &c. In the low-lying alluvial islands at the mouth of the Thames, some very deep wells were also sunk through the London clay, and a copious supply of fresh soft water was obtained; and, in fact, so many wells have been sunk into the water-bearing strata of the tertiary sands, that they have been nearly exhausted. Whilst these operations were being carried on in England, the French engineers had energetically adopted the system upon which they were founded, and numerous artesian wells had been sunk at Epinay, Stans, and St. Denis, with similar results to those obtained near and in London, that is to say, that in the earlier wells the water, generally speaking, overflowed the surface, whilst in the latter ones it rarely attained the level of the ground; and the water-line sank in the older wells in proportion as new ones were opened.

In 1833 M. Arago induced the Conseil Municipal of Paris to undertake the execution of a deep boring, in the hope of obtaining a supply of water from the lower green sand formations, which he supposed to form a continuous bed under the chalk basin, underlying, in its turn, the tertiary strata of the neighborhood of Paris. This lower green sand, in fact, outcrops from under the chalk on the whole of an irregular oval, passing from the north-east through the south, nearly to the north-west of Paris, and it approaches that city the most nearly at the point where the Seine forces its way through the overlying recent formations near Troyes, in Champagne. At Lusigny, the precise point of outcrop, the surface of the green sand is about 300 or 350 feet above the level of the plain of Grenelle, where it had been resolved to make the first attempt to traverse the tertiaries and the chalk. From this fact, MM. Arago and Walferdin inferred that the water from the green sand would flow over the surface at Grenelle, and they were

encouraged in that opinion by the existence of numerous artesian wells carried through the chalk into that stratum, from which they expected to obtain their supply at Elbœuf and Rouen. The depth it would be necessary to sink the new well constituted the unknown conditions of their undertaking; but not only MM. Arago and Walferdin, but also M. Mulot, calculated from the first that they would find the chalk extend to at least 1300 to 1400 feet from the surface. So little, however, was known of the probable cost, or of the dangers and risks of these deep borings, at the time the well of Grenelle was commenced, that the municipality of Paris only voted a sum of 18,000 francs (£720) for boring three such wells.

On the 29th of November, 1833, the works of the Grenelle well were commenced by M. Mulot, and after encountering many serious difficulties from the nature of the ground, and from the fracture of the tools made to work at so great a distance from the surface, the able and scientific men who had supported M. Mulot through evil report and bad report, were rewarded by finally obtaining a copious jet of water from the lower green sand on the 26th February, 1841. The depth then reached was 1806 feet 9 inches, of which 1378 feet were in the chalk; the water rose at first at the rate of 800,000 gallons per day, to the height of about 122 feet (the level of the distributing reservoir of Grenelle), and its temperature was about 82° Fahrenheit. When it first rose to the surface, it contained large quantities of sand, clay, and other matters in mechanical suspension, and it was nearly 12 months before the water passages of the subterranean strata were sufficiently cleared to allow the water to rise in a state fit for distribution. On several subsequent occasions also, the sand has accumulated in such quantities, in the pipes lining the bore, as to render it necessary to draw and clean them.

This boring operation had been watched very carefully by English engineers, and even during its progress similar works had been attempted in our own country. As might naturally have been expected, the success of the Grenelle well, under these circumstances, induced our countrymen to continue their work with redoubled ardor, but unfortunately they have displayed less perseverance, and it is to be feared less skill, than our neighbors; for hitherto none of the deep borings undertaken avowedly for the purpose of obtaining a supply of water from the subcretaceous beds in either the London or the Hampshire basins, have completely succeeded. In the case of the Kentish Town well, it is true that some very extraordinary and anomalous conditions of the strata have been found to exist, which have totally deranged all the scientific calculations of the able geologists and well-borers consulted during its execution; but it has too often happened in England, that works of the kind we are now considering have been undertaken solely on the recommendation of amateur geologists, or of "practical men," as it is the fashion to call those who are totally ignorant of recorded science; and the consequence has been that several very costly wells have been undertaken, carried on at great expense, and subsequently abandoned in despair, perhaps just at the moment when success was within grasp.

One of the earliest of the attempts made in England at sinking an artesian well to the lower green sand, was the one made, almost unintentionally, by the town of Southampton. It was commenced by a preliminary boring through the London clay to the chalk, which was reached at a depth of 480 feet from the surface, the upper strata traversed consisting of the sands, clays, and plastic mottled clays of the Hampshire tertiary series. It seems that the well-borer employed carried the boring to a depth of 50 feet beyond the surface of the chalk already mentioned, and he then reported that an ample supply of water was to be obtained from that formation. A shaft was sunk on faith of this report, commencing with a cast iron lining of 13 feet diameter, which it was proposed to carry to a depth of 160 feet, and then to commence boring with a hole of 30 inches diameter, diminishing gradually to 20 inches in the chalk. The cylinders used were, however, found to be too weak for the purpose they were intended to fulfil; they collapsed in places, and, in driving, they assumed a direction seriously out of the perpendicular. The contractor failed when the cylinders had been thus badly lowered to the depth of about 60 feet, and the works were then taken out of his hands, and placed in those of Mr. Docwra, one of the most able well-sinkers and water works contractors of our country and of our day. With great trouble he drove the shaft completely down to the chalk, finishing it with a clear external diameter of 9 feet 4 inches; part of it was lined with cast iron plates, and part of it with brickwork in cement. The brickwork lining was carried three feet into the chalk, and below it the shaft was continued to the total depth of 562½ feet from the surface, in the solid chalk, without any lining, and with a clear diameter of about 7 feet; a boring was then commenced of 7½ inches diameter, and was carried down eventually to a total depth of 1317 feet from the surface. The chalk formation was found here to have a thickness of 851 feet, and the works were suspended when the boring had traversed only 12 feet of the chalk marl. Now at Chichester, where Mr. Gatehouse had also sunk a deep well to the upper green sand about the same period, the thickness of the chalk marl was found to be 61 feet; the upper green sand and gault are of variable thicknesses, but the greatest depth recorded for them was that of the new well at Passy, where they were about 274 feet deep. It is, therefore, very probable, that if the Southampton well had been carried down 330 feet further, or to a total depth of 1650 feet in round numbers, the problem as to the possibility of finding water from the lower green sand, in the Hampshire basin, might have been solved. In the well at Chichester this solution could be even more easily attained, for the boring had actually been carried about 180 feet nearer to the probable surface of the lower green sand, leaving only 200 feet still to be traversed.

It would be impossible to record all the important works undertaken of late years for obtaining water by means of artesian wells, but the circumstances connected with the history of those attempted at Calais, Kentish Town, and Harwich, are so singular, that it behooves us to dwell upon them. At Calais the well was sunk through the chalk, and the whole series of the subcretaceous strata, to a total depth of 1047

feet from the surface, but no water was obtained from it, and the boring passed, at the depth above-named, into the transition rocks, in which it was carried for a further depth of 103 feet. At Kentish Town, the Hampstead Water Works Company endeavored to secure an artesian supply, in order to comply with the provisions of the Metropolis Water Works Act of 1851. They had very wisely consulted Mr. Prestwich upon the geological questions involved in the preliminary inquiries, and they employed Messrs. Degoussé and Laurent, the best known and most successful well-borers up to that period, on the Continent. Geologists and practical men alike in this instance reasoned that, because the lower green sand outcropped around the edges of the chalk basin containing the Paris tertiaries, therefore, there was every *à priori* reason to believe that the subcretaceous formations would continue under London, and furnish, as had been the case at Paris, the water for a well carried down to them. Acting upon this belief, the company commenced boring in the chalk, at the bottom of a shaft previously sunk to the depth of 539 feet from the surface. The boring was commenced with a diameter of 12 ins., reduced to 10 ins. in the intermediate part, and finishing with a diameter of 8 ins. The work began on the 10th of June, 1853, and was carried on with every appearance of success for a considerable time. The strata traversed were found to occur in their regular order, and of the anticipated thicknesses, until the boring had traversed the gault formation at the depth of 1113 feet 6 inches from the surface; but when, as Mr. Prestwich said, every body believed that "a very few more turns of the auger would tap the water-bearing sands of the lower green sand formation," it was found that the borings passed at once into a series of beds consisting of alternate layers of red sandstones, red clays, conglomerates, red sands, and rounded pebbles, which geologists are now disposed to class amongst the new red sandstone series. It is very difficult to form any decided opinion as to the real nature of a deposit which has only been explored by the boring tool, especially when the diameter of the bore was only eight inches, as at Kentish Town; and I confess that for my own part, as I said before in this room, and shall have occasion again to repeat, I am disposed to regard the beds of red clays and sandstones rather as being members of the Wealden series than of the new red sandstone. But in either case it was evident that the water-bearing strata were interrupted under London, and that there was no probability of obtaining a supply of any description from them in that district. In fact, the Hampstead Water Works Company, after the failure of this attempt, were compelled to sell their interests to the New River Company, and the well was stopped at the depth above quoted, added to the depth traversed in red sandstones and clays, or at a total depth from the surface of 1302 feet.

About the same time that this unexpected result was obtained at Kentish Town, Mr. P. Bruff, C. E., was employed upon an attempt to obtain water for the town of Harwich, either by a deep well in the chalk, or by traversing, if necessary, the strata below the chalk. Several attempts appear to have been previously made at Harwich to obtain a supply from the chalk, but they had failed, in consequence of the in-

filtration of salt water into the wells sunk close to the sea shore. Mr. Lankaster Webb, of Stowmarket, a town situated upon the high lands of the valley of the Gipping, the main affluent of the Orwell, had executed a well 895 feet deep, through the drift clays and gravels over the chalk, the cretaceous formations, and the upper green sands and gault. I do not know the level of the ground at Mr. Webb's factory, but as a rough guess I should say that it was about 240 feet above the high tide level at Harwich; and I am not, therefore, surprised that the persons connected with the well at the latter town should have expected, that upon traversing the chalk they would meet with a supply of water under the true artesian conditions. It happened, however, that after the Harwich boring had passed through the drift, the tertiary strata, the chalk, the upper green sand, and the gault, to the depth of 1025½ feet from the surface, it passed, not into the lower green sand, but into a black slaty rock, which Mr. Prestwich pronounced to be a common grey slate of the palæozoic series, whose precise position in the series could, however, hardly be defined, on account of the absence of fossils. Thus at Calais, and I believe also at Ostend, the lower green sand is wanting, and is replaced by a member of the carboniferous series; at Kentish Town the lower green sand is absent, and it is replaced perhaps by the new red sandstone beds, whilst at Harwich the lower green sand is replaced by the very earliest clay slate rocks.

Now, there may be drawn, from these unexpected results of the deep borings in the tertiaries of what may be specially named the London basin, some valuable scientific and practical conclusions. These may be briefly stated as follows:—1st, That at present, geology is only so far advanced as to enable us to state, with tolerable certainty, what we shall not find under the surface, but by no means to justify any positive assertion as to what we shall find: thus, knowing that the London clay is on the surface, we may be certain that the crag will not be found beneath it; but it by no means follows that necessarily the chalk, the lower green sands, the oolites, or the usually subordinate strata, should be there. 2d, That the first attempt to sink an artesian well through a previously untried stratum, is at all times a hazardous experiment, and that it is, therefore, one which should never be tried by those who only work with the money raised by forced taxation. It was upon the latter ground that Mr. Ranger very properly recommended the town of Southampton to stop the philosophical experiment upon which they had already incurred so large an outlay; and it is certainly wiser to leave the solution of these problems to municipalities possessed of private resources, or to private enterprise, than to expend upon them the money wrung from the rate-payers. 3d, And possibly this may be the most important conclusion of all—it would appear to be proved by the occurrence of the earlier strata in the geological series at Calais, Kentish Town, Harwich, and, if I be not mistaken, at Ostend also, that Mr. Goodwin Austin's theory of an upheaval of the carboniferous series existing between its extremity on the French coast, and its reappearance in the Bristol and the South Wales coal field, is correct. A full discussion of this important inquiry

would be misplaced in this paper, but I cannot refrain from repeating what I myself have said before, viz: that from all which is at present known, it would be more rational to seek for coal under London, than for soft water. At the same time, I would guard myself against any appearance of encouraging an attempt of the former description, unless it were distinctly undertaken as a speculation, with great, nay, almost infallible chances of loss.

The next important artesian borings executed of late years in chronological order, were those undertaken under the superintendence of the French military authorities in the Desert of Sahara, avowedly for the purpose of forming stations for the caravans trading between Algeria and Central Africa. They were executed by means of tools made by Messrs. Degoussé and Laurent, who seem also to have occasionally acted as consulting engineers, but the works were actually performed by the soldiers, or the laborers employed by the "Corps due Genie Militaire." It appears that up to the month of June, 1860, no less than 50 of these wells have been sunk in the desert, and that they pour upon its thirsty surface no less than 7,920,000 gallons of water per day. Similar works were, according to Aime Bey, executed in the deserts of Ancient Egypt, as was before alluded to, and there are good reasons for believing that the system of artesian borings might advantageously be applied in the deserts of north-western India and Australia.

(To be Continued.)

The Economic Construction of Girders.

From the Lond. Civ. Eng. and Arch. Journal, June, 1862.

(Continued from page 156.)

Since writing the last article on this subject, we have calculated the practical weights of several other forms of openwork girders of similar proportions to those already given, and as several of these new forms possess considerable economic merit, and the whole will form a pretty complete investigation of this particular group of girders—having a depth equal to one-eighth of the span, the roadway divided into eight bays, the fixed loading equal to half a ton, and the movable loading equal to one ton per foot run—it is desirable that the calculations of these new forms should also be given in detail, and the results for all the forms collected together in one table.

We group the results under the two distinct cases of the roadway platform being placed—1st, at or above the level of the upper boom of the girder; and, 2d, at or below the level of the lower boom. We advisedly omit the case of the roadway being placed at the level of the neutral axis; such a position must generally entail the employment of much extra material, and has nothing to recommend it, at least when openwork girders are employed.

Although the table of results shows that the girders taken alone may be made decidedly lighter for the second case than for the first, yet for various economic reasons, the first arrangement, or that in

which the roadway rests on the tops of the girders, is to be preferred when the choice can be made. Of these reasons for the preference we may mention the following:—First, lightness of the transverse girders; when single principal girders are used in a railway bridge, one being placed immediately beneath each rail, transverse girders may be got rid of altogether, without the use of unduly thick planking; and when the girders are double ones, or each capable of supporting one complete line of railway, the distance between them, or the length of bearing for the transverse girders, may be only 11 or 16 feet; whereas, in the case of the platform being at the lower boom level, the lengths of bearing for the transverse girders must be respectively about 14 and 25 feet, according as single or double principal girders are employed. The second reason is, that free scope is allowed for the introduction in the best manner of the necessary horizontal and transverse bracings; with the consequent lightness and perfection of action of these elements of the structure. The third reason is, that with the roadway at the top rather than at the bottom level of the girders, the total height of the structure is less by a length equal to the depth of the girder.

There should then, when economy and excellence of construction are considered, be no hesitation in adopting the first arrangement, whenever the circumstances admit of it. But very frequently this cannot be, as the arrangement would not allow of sufficient headway beneath the girders for the requirements of the road or river bridged over.

When constrained to place the roadway platform at the lower level of our girders, it will be a source of great advantage if we can have these so deep that the upper booms may be connected together overhead by a horizontal bracing; for in the absence of such a connexion a considerable addition of material in the upper booms to prevent lateral warpings and consequent failure would be demanded. But with the girders we are considering, or others of great proportionate depth, it will only be for trifling spans that this knitting together of the two booms cannot be managed. By attaching the transverse girders so that their tops come in contact with the under surfaces of the tie-booms, a clear height above the rails and below the upper horizontal bracing, equal to the depth of girder for calculation, may be readily secured; so that with girders eight depths in span, we may use the connected arrangement, although the span be even somewhat less than 120 feet. And for spans considerably less than this it may still be advisable to adopt this tubular arrangement, by retaining the necessary depth of girder; for instance, for a span of about 90 feet, we could have the depth of girder equal to one-sixth the span.

When the spans and consequently the depths are great, and the road at the lower boom level, a light line of horizontal bracing may be run along the neutral plane, or near to it—this will add greatly to the stiffness of the struts of the web, so that the allowance of metal (*a*) given to them may be considerably reduced. In fact, with such a support against lateral bending and the support in the plane of the girder afforded by the crossing ties in the first form of girder, the

lengths of the struts of the bracing would be virtually reduced to one-half.

For either position of the roadway, it will generally be best to adopt one of those forms the results for which are given in the *last* column of Table XXXII. For with such the piers need not be carried up beyond the lowest member of the girder.

It may here be proper to give some further particulars of the principles on which the values of the factor a for the various parts are assigned; particularly as these may not be thought very correct by some readers. And it is for this reason that the calculations are given in such detail, that the results with other values of a (either more correct or in accordance with the practice of other constructors) may be readily computed.

The general dimensions and character of the sections of the booms will be chosen with reference to the greatest stress to be borne, which is here at the midspan; and this must lead to a large excess of metal being given to the less strained bays, so much so that in the girders we are considering, the extreme bays may be taken as not reducible below the following per centages of the strongest or central bays when a proper regard is paid to firm and durable construction:—for the sectional area of the extreme bay of the strut-boom we give about 66 per cent. of the section at the midspan, and for that of the extreme bay of the tie-boom, about 35 per cent. of its central section.

Then with regard to the struts of the bracing—the sections of these have in a general sense been taken from actual fabrics. It may be noticed in the first place, that when the vertical component, v, of the stress is the same for a perpendicular as for an oblique brace, the value of a has been chosen the same for each; the reason for this being that the actual stresses ($= v \sec \theta$) in proportion to the lengths are the same. Such a rule would not be correct were the struts all of solid section, or all of exactly similar sections, but when the struts are built up of plates and angle irons, the rule is, within reasonable limits, practically very near to the truth. Again, if we take the case of a strut, say strut A of Table I, which receives support in *one* direction only, from the tie H, crossing and being attached to it at its middle, we find $a = \cdot00060$; then turning to the similar strut A of Table XV., which receives no such support, we yet find the value of a still $= \cdot00060$; the reason for this is that the latter strut has to carry a stress whose vertical component is equal to $10\frac{1}{2}$ units, whereas the former strut has a value of v equal to only 6 units; the sectional areas will therefore be in these proportions, and it is assumed that the excess of section in the latter will be sufficient to make up for the loss of assistance from a crossing tie.

If the depths of the girders were reduced from one-eighth to one-sixteenth of the span, the lengths of the braces and of the bays would be reduced by one-half, and the stresses in the booms would be doubled. Such changes would indicate a reduction in the values of a for all the struts (although the allowance for extra length in the braces might require to be increased), and from the stouter section that could be used for the upper boom its end-bays might be reduced in section-

al area, to say 60 per cent. of the central ones, and the end-bays of the ties to one-third. We have run out the calculations for such girders—but neither the details nor results are of sufficient interest to call for their being given here. The results are, indeed, only what might have been predicted—viz., the weights of the booms rather less than the double of those for girders of double the depth, and the weights of the webs rather less than those for the deeper girders. Further, the influence of the value of θ, the angle of inclination of the braces, is augmented in affecting the weight of the web in each example, but as the web constitutes only about one-fifth of the whole weight of the girder, instead of one-third as in the deeper forms, the importance of an apparently considerable saving on it is greatly reduced when estimated as a per centage over the whole structure; thus, in the examples having a depth of one-eighth of the span, a saving on the web amounting to 15 per cent. would represent a saving of 5 per cent. on the complete girder, but when the depth is only one-sixteenth of the span, to produce this saving on the whole girder would require the saving on the web to amount to 25 per cent.

When the girders are single, *i. e.*, only calculated to carry a movable loading equal to half a ton per foot run, and at the same time the span is moderate, a marked addition must be made to the values of a for the struts, particularly in those of the web. From this it will be seen that single girders when of moderate span, must weigh considerably more than half the corresponding double ones; it is therefore advisable where practicable, as in the case of the roadway being at the upper level, to employ two double girders in preference to four or more single ones. For very long spans, the preference for various reasons may, on the contrary, be given to single girders.

We may now proceed to describe the various forms of girder, the results for which are contained in Table XXXII, and to give the details of the remaining calculations.

The first, second, third, and fourth forms, have already been described in the former paper.

The fifth form is a frame with a single series of braces, or what is known as a warren-girder, commencing with a tie-brace, and with $\theta = 26° 34'$ throughout.

The sixth form is also a warren-girder, with the same value of θ, but commencing with a strut. It should be observed that for these two forms, when the roadway is at the lower and at the higher levels respectively, the distribution of the loaded points along the span becomes different from that in the other examples, and the amount of loading due to each of the extreme points is only three-quarters of that due to each of the others; this, as has been shown in a former paper, gives rise in itself to some change in the general results.

The seventh form is identical with the third, except that the tie H of the third is replaced by a strut A introduced in the other diagonal of the end quadrilateral compartment, and the vertical strut A of the third form is converted into the vertical tie H of the seventh.

The remaining forms are modifications of the preceding seven, made in order to suit them better for the particular cases.

The eighth form is the first modified, to carry the road at the upper level, and also to deliver the load at that level to the piers.

The ninth form is the first modified, to carry the load at the lower level, and to deliver it at that level to the piers; this gives the most economical of all the arrangements, although not much more so than the fourteenth form, which further, from having the struts of the web at right angles to the booms, may offer some constructive facilities.

The tenth form is the third modified, for an upper load, and an upper bearing on the piers.

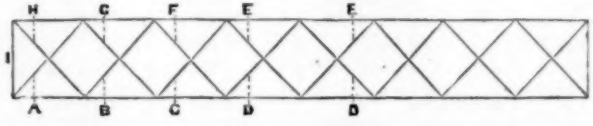
The eleventh form is the fourth modified, to carry the roadway at the lower level, and to have its bearings on the piers at that level.

The twelfth form is the fifth or warren form, hung at the upper angles, and with the end pillars and extreme half bays of the tie-boom omitted.

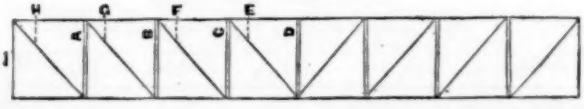
The thirteenth form is the sixth, bearing on the piers at the lower angles, and with the end pillars and extreme half bays of the top boom omitted.

The fourteenth form is the seventh, modified for a load at the lower level, and a bearing on the piers at that level. This form possesses great economic merits, and may be looked upon as competing with the ninth for the first place, for the case of the roadway being placed at the level of the lower boom, and when there is to be but one span, or no connexion with other spans over the piers. For the case of the roadway being placed at the level of the upper boom, the first form must still be regarded as holding the first place, whether for bridges with separate or connected spans.

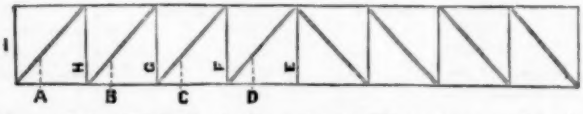
First Form.



Third Form.



Fourth Form.



Calculations of the Weight of Iron in the Bracings and end Pillars, and in the Booms of the several forms of Girder.

The unit of length is taken equal to the depth of the girder, or to one-eighth of the span.

The unit of stress or load is taken equal to one-eighth of the total

dead weight, or to one-sixteenth of the whole movable loading that may be brought upon the girder.

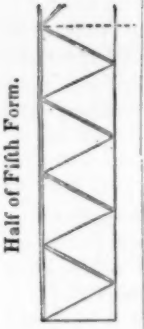
The measure of the weight of iron in any part, as given in the tables, is equal to the greatest stress that may act upon it multiplied by its theoretical length in the above units, and by the factor a; and this in the case of a brace will be $= \mathrm{V} \sec^2 \theta$, where V represents the vertical component of the stress, and θ the angle which the brace forms with a vertical line.

The actual weight of iron in any brace or bay in tons will be obtained by multiplying the representative number in the table by the product in feet-tons of the units of length and stress. For the whole weight of the web or booms of a girder we must further double the results in the tables, since these are given for only half the length of the girder; or as explained before, we must multiply the tabular number by the square of the depth of the girder in feet, to obtain the weight in tons.

The calculations for the first four forms have already been given.

THE FIFTH FORM, with the loading at the upper level.

TABLE XVIII. The Web.



Brace.	a.	V.	$\mathrm{Sec}^2\,\theta$.	Weight.
A	·00060	10·50	1·25	·00787
B	·00067	7·75	1·25	·00649
C	·00077	5·25	1·25	·00505
D	·00090	3·00	1·25	·00338
E	·00045	3·00	1·25	·00169
F	·00045	5·25	1·25	·00295
G	·00045	7·75	1·25	·00436
H	·00045	10·50	1·25	·00591
				·03770
I as a tie,	∞	0·00	1·00	·00075
I as a strut,	·00060	12	1·00	·00720

TABLE XIX. The Booms.

(N. B.—Each ordinary bay is one unit long).

Upper Boom.	a.	Stress.	Weight.
1st Bay	·00160	5·25	·00840
2	·00070	14·25	·00997
3	·00060	20·25	·01215
4	·00055	23·25	·01279
			.04331
Lower Boom.			
1st Bay ½	∞	0·00	·00189
2	·000	10·50	·00473
3	·000	18·00	·00810
4	·000	22·50	·01012
5 ½	·000	24·00	·00540
			·03024

THE FIFTH FORM, with the loading at the lower level.

TABLE XX. The Web.

Brace.	a.	v.	Sec $^2\theta$.	Weight.
A	·00062	9·094	1·25	·00705
B	·00070	6·469	1·25	·00566
C	·00080	4·094	1·25	·00410
D	·00110	1·969	1·25	·00271
E	·00045	4·093	1·25	·00230
F	·00045	6·469	1·25	·00364
G	·00045	9·093	1·25	·00511
H	·00045	11·250	1·25	·00633
				·03690
I as a tie,		0·750	1·00	·00080
I as a strut,	·00060	11·250	1·00	·00675

TABLE XXI. The Booms.

Upper Boom.	a.	Stress.	Weight.
1st Bay	·00152	5·625	·00855
2	·00070	14·625	·01024
3	·00060	20·625	·01238
4	·00055	23·625	·01299
			·04416
Lower Boom.			
1st Bay $\frac{1}{2}$	∞	0·000	·00186
2	·00045	10·125	·00456
3	·00045	17·625	·00793
4	·00045	22·125	·00996
5 $\frac{1}{2}$	·00045	23·625	·00531
			·02962

The Booms as before = ·07300.

THE SIXTH FORM, with the loading at the upper level.

TABLE XXII. The Web.

Brace.	a.	v.	Sec $^2\theta$.	Weight.
A	·00060	11·250	1·25	·00844
B	·00063	9·093	1·25	·00717
C	·00070	6·469	1·25	·00566
D	·00080	4·094	1·25	·00409
E	·00110	1·969	1·25	·00271
F	·00045	4·093	1·25	·00230
G	·00045	6·469	1·25	·00364
H	·00045	9·093	1·25	·00511
				·03912
I as a strut,		0·750	1·00	·00200
I as a tie,	·00045	11·250	1·00	·00506

Half of Sixth Form.

TABLE XXIII. The Booms.

Upper Boom.	*a*.	Stress.	Weight.
1st Bay ½	∞	0	·00420
2	·00086	10·125	·00871
3	·00065	17·625	·01146
4	·00058	22·125	·01283
5 ½	·00055	23·625	·00650
			·04370
Lower Boom.			
1st Bay	·00066	5·625	371
2	·00045	14·625	658
3	·00045	20·625	928
4	·00045	23·625	1063
			·03020

THE SIXTH FORM, with the loading at the lower level.

TABLE XXIV. The Web.

Brace.	*a*.	v.	Sec $^2\theta$.	Weight.
A to H	Same as in Table XVIII.		= .	·03770
I as a tie,	·00045	12·00	1·0	540
I as a strut,	∞	0	1·0	200

TABLE XXV. The Booms.

Upper Boom.	*a*.	Stress.	Weight.
1st Bay ½	∞	0 0	·00420
2	·00084	10·5	·00882
3	·00065	18·0	·01170
4	·00058	22·5	·01305
5 ½	·00055	24·0	·00660
			·04437
Lower Boom.			
1st Bay	·00068	5·25	·00357
2	·00045	14·25	·00641
3	·00045	20·25	·00911
4	·00045	23·25	·01046
			·02955

THE SEVENTH FORM, with the load at the upper level.

TABLE XXVI. The Web.

Brace.	*a*.	v.	Sec $^2\theta$.	Weight.
A . . .	·00060	10·5	2	·01260
B to G as in Table V.			=	·02498
H . . .	∞	0	1	·00060
				·03818
I as a tie, .	·00045	10·5	1	·00479
I as a strut, .	·00120	1·5	1	·00180
			The Booms =	·07300

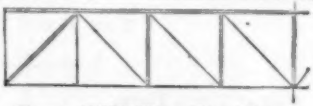
The weight of the booms in this and the next arrangement may be taken the same as for the third form (Table XIV). The first bay of the upper boom is relieved from all longitudinal stress, and the first bay of the lower boom bears a stress of 10·5; any slight change in the sections of these parts which such differences could warrant, would neutralize one another; and the other bays are all exactly as before.

THE SEVENTH FORM, with the load at the lower level.

TABLE XXVII. The Web.

Brace.	*a*.	v.	Sec $^2\theta$	Weight.
A . .	·00060	10·50	2	·01260
B to G as in Table VI.			=	·02184
H . .	·00045	3·0	1	·00135
				·03579
I as a tie, .	·00045	12·00	1	·00540
I as a strut,	∞	0	1	·00200

Half of Seventh Form.



THE EIGHTH FORM. TABLE XXVIII. The Web.

Brace.	*a*.	v.	Sec $^2\theta$.	Weight.
A . .	·00067	6·0	1	·00402
B to G as in Table I.			=	·02176
H . .	·00045	10·5	2	·00945
				·03523

Half of Eighth Form.

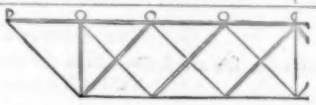


TABLE XXIX. The Booms.

Upper Boom.	*a*.	Stress.	Weight.
1st Bay, . .	·00080	10·5	·00840
2d to 4th as in Table X.		=	·03353
			·04193
Lower Boom. Same as in Table X., without 1st Bay,		=	·02709

THE NINTH FORM.

Half of Ninth Form.

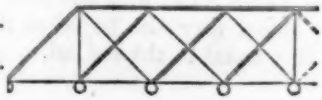


TABLE XXX. The Web.

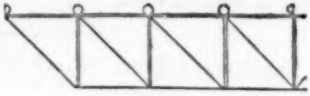
Brace.	a.	v.	$\text{Sec}^2\,\theta$.	Weight.
A . .	·00060	10·5	2	·01260
B to G } as in Table II.			=	·01971
H . .	·00045	6·0	1	·00270
				·03501

TABLE XXXI. The Booms.

			Weight.
Upper Boom same as in Table XI., wanting 1st Bay,		=	·03630
Lower Boom.			
1st Bay, . .	= ·00045 × 10·5 .	=	·00473
2d to 4th same as in Table XI,	. . . .	=	2497
			·02970

THE TENTH FORM.

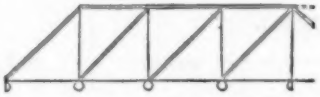
Half of Tenth Form.



The results for this are obtained from the data in Tables V, and XIV.

THE ELEVENTH FORM.

Half of Eleventh Form.



The results for this are obtained from the data in Tables VIII, and XV.

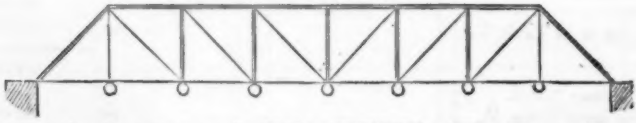
THE TWELFTH FORM.

The results for this are derived from the data in Tables XVIII and XIX, and Tables XX and XXI.

THE THIRTEENTH FORM.

The results for this are derived from the data in Tables XXIV and XXV.

THE FOURTEENTH FORM.



The Web is the same as in Table XXVII. The Upper Boom may be taken from Table XIV, with the first Bay omitted.

The Lower Boom may also be taken from Table XIV, after making the first Bay equal to the second.

TABLE XXVII. General Summary of Results for the Girders.

TABLE XXXII. GENERAL SUMMARY OF RESULTS FOR THE GIRDERS.

DESCRIPTION OF THE GIRDER.	RESULTS FOR THE WEB.			RESULTS FOR BOOMS.			RESULTS FOR THE GIRDER COMPLETE.		
	Without end pillars, or as described in column 8.	With end pillars as ties, or as described in column 9.	With end pillars as struts, or as described in column 10.	Upper Boom.	Lower Boom.	Total.	Without end pillars; *i. e.*, attached to the piers by all the extremities of the booms.	With end pillars as ties; or otherwise the girder wholly supported at the extremities of the upper boom.	With end pillars as struts; or otherwise the girder wholly supported at the extremities of the lower boom.
1st Case—Load at Top									
1st Form,	·0330	·0357	·0366	·0416	·0310	·0726	·1057	·1084	·1093
2 "	·0322	·0349	·0358	·0460	·0293	·0753	·1076	·1103	·1112
3 "	·0407	·0415	·0479	·0465	·0265	·0730	·1137	·1145	·1209
4 "	·0440	·0487	·0458	·0396	0337	·0733	·1173	·1220	·1191
5 "	·0377	·0384	·0449	·0433	·0302	·0735	·1112	·1120	·1184
6 "	·0391	·0442	·0411	·0437	·0302	·0739	·1130	·1180	·1150
7 "	·0382	·0429	·0400	. .	. .	·0730	·1112	·1159	·1130
8 "	. .	·0352	. .	·0419	·0270	·0689	. .	·1042	. .
10 "	. .	·0407	. .	·0465	·0229	·0694	. .	·1101	. .
12 "	. .	·0377	. .	·0433	·0284	·0717	. .	·1094	. .
2d Case—									
Load at Bottom.									
1st Form,	·0310	·0337	·0346	·0447	·0286	·0733	·1042	·1069	·1078
2 "	·0302	·0329	·0338	·0458	·0270	·0727	·1030	·1057	·1066
3 "	·0363	·0372	·0426	·0464	·0266	·0730	·1093	·1102	·1156
4 "	·0476	·0530	·0496	·0396	·0337	·0733	·1210	·1264	·1230
5 "	·0369	·0377	·0436	·0442	·0296	·0738	·1107	·1115	·1174
6 "	·0377	·0431	·0397	·0444	·0295	·0739	·1116	·1170	·1136
7 "	·0358	·0412	·0378	. .	. .	·0730	·1088	·1142	·1108
9 "	. .	. .	·0350	·0363	·0297	·0660	. .	. .	·1010
11 "	. .	. .	·0476	·0316	·0337	·0653	. .	. .	·1130 *
12 "	. .	·0369	. .	·0442	·0227	·0719	. .	·1088	. .
13 "	. .	. .	·0377	·0402	·0295	·0697	. .	. .	·1074
14 "	. .	. .	·0358	·0379	·0277	·0656	. .	. .	·1015

(To be Continued.)

Edinburgh.

* The result given for this form at end of Table XVII, (page 153) was incorrect.

R. H. B.

Strain on Arches and Suspension Chains.

From the London Artizan, July, 1862.

The arch and suspension chain are identical in principle, the only difference between them being that the arch is subjected to compression, and the suspension chain to tension.

The suspension chain being flexible can be altered in its form by any partial load, which the arch cannot. If we suppose a chain supported at its ends by two points infinitely close together, then the chain is subject to the least tensile strain, having only its own weight to carry; if these points be gradually removed from each other, the tensile strain will continually increase until the chain is straight, when it will assume the condition of a straight girder, and be subject to both tension and compression. If it now begins to curve upwards the strain will become wholly compressive, and the structure will be an arch. As the points of support are brought closer together, the strain continues to decrease until the points of support become one, when the strain is at a minimum, and the conditions of a column are assumed.

Arches are constructed of various forms, although a parabolic curve seems to be most suitable.

The form which a uniform chain or cord assumes when freely suspended from two points is termed the catenary curve, and this is always assumed when the chain has only its own weight to carry; but if the chain were devoid of weight and a uniformly distributed load were suspended from it, the form of the chain would be that of the parabola. In practice the form of the chain is influenced both by its own weight and by the load; it is therefore some curve intermediate between the catenary and parabola, approaching one or the other, as the chain or load becomes heavier, but it usually approaches nearer to the parabola than to the catenary. The true form of the curve has been demonstrated by Professor Moseley, but it is sufficient for all practical purposes to consider it as a parabola.

Before proceeding to the determination of the strains upon arches and suspension chains, we will give a formula for finding the length of the suspension rods and of the chain, on the supposition of its forming a parabola.

Let l = length of any suspension rod.
l_1 = length of shortest suspension rod.
d = deflection of chain.
s = semispan.
x = distance of suspension rod from centre of chord.
L = length of half the chain.

Then

$$l = l_1 \times \frac{d\,x^2}{s^2}$$

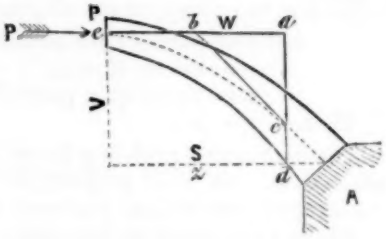
$$\text{L} = \sqrt{s^2 + \frac{4}{3}d^2}$$

Theory of the Arch.—Let A B (Fig. 1) represent half an arch subject to a uniformly distributed load.

Let P = horizontal pressure produced by the other part of the arch.
W = total load on the arch.
W_1 = load between the centre of the arch and any section.
S = the span.
V = versine to the line of resistance.

From the point *e* at the centre of gravity of the section draw the horizontal line *a e*, which is the direction of the horizontal pressure P. From *a* let fall the perpendicular *a d*; then the forces acting on a section *c* will be represented by the sides of the triangle *a b c*, *a b* being equal to P, the horizontal pressure, and *a c* equal to W, the vertical load; *b c* will be the resultant of these two forces.

Fig. 1.



We first find the form assumed by the line of resistance; *c* the intersection of *c b* with *a d*, being one point in the line, and *e* another.

Let R = the thrust at the point *c*.
$a = > a\,b\,c$ = inclination of curve of resistance at *c*.

Then,
$$W_1 = P \tan.\ a.$$
$$R = \sqrt{(P^2 + W_1^2)} = P \sec.\ a.$$

To obtain from these an equation to the curve, let that curve be referred to rectangular co-ordinates, horizontal and vertical, commencing at *e*, the highest part, and call $a\,e = x$, $a\,c = y$; then,

$$\tan.\ a = \frac{d\,y}{d\,x} \qquad \therefore \qquad \frac{d\,y}{d\,x} = \frac{W_1}{P} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

From this equation, the equation to the curve may be obtained when the distribution of the load is known.

Let w = load per foot lineal. $\therefore$ $W_1 = w\,x$, and the equation (1) becomes
$$\frac{d\,y}{d\,x} = \frac{w\,x}{P}$$

This being integrated, remembering that when $x\,o = y = o$
$$y = \frac{w\,x^2}{2\,P}$$ which is an equation to the parabola.

Hence it appears that the curve of resistance is a parabola.

Let β = the angle made with the horizon by a tangent, the curve at its point of intersection with the abutment.

Then for the thrust at the centre of the arch we have
$$P = \frac{W}{\tan.\ \beta} = \frac{W\,S}{8\,V}$$ for the thrust at any section *c*.

$$R = \sqrt{\frac{W^2\,S^2}{64\,V^2} + W_1^2}$$ for the thrust at the abutment.

Let T = the thrust.

$$T = W\sqrt{\frac{s^2}{64\ v^2} + \frac{1}{4}}$$

Arch for Uniform Fluid Pressure.—It is evident that an arch to resist a uniform fluid pressure from without should be circular, because as the force to which it is subjected is similar all round, its figure should be similar all round.

To find the thrust on the ring or circular arch,

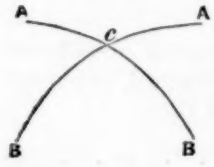
Let p = pressure per square foot on the circumference.
r = radius of ring.
T = thrust on a part of the ring one foot in width.

Then, $T = p\ r$.

The hydrostatic arch is a linear arch, suited for sustaining normal pressure at each point proportional to the depth below a given horizontal line, such as that produced by a liquid in repose.

To have the thrust on the arch uniform, the radius of curvature at any point should be inversely as the pressure at that point. The thrust on the arch is equal to the pressure multiplied by the radius of curvature. The hydrostatic arch is found to present some resemblance to a trochoid, but it is not identical with that curve.

Fig. 2.



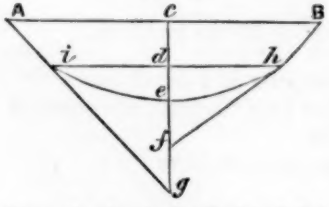
Pointed arches.—If a linear arch, as in Fig. 2, consists of two arcs B C, C B, meeting in a point at C, it is necessary to equilibrium that there should be concentrated at C, a load equal to that which would have been distributed over the two arcs A C, C A, extending from the point C to the respective crowns A A of the curves, of which two portions form the pointed arch.

Theory of Suspension Chains.—The form of the curve assumed by the chain, and the formulæ relating to it, have already been given.

The strains on a suspension chain may be determined in a manner precisely similar to that applied to the arch. We shall, however, further investigate the strains upon it by another method.

Let A B (Fig. 3) represent a suspension chain; g B is a tangent to the curve at the point of suspension, making an angle θ with the horizontal chord A c B; $h\ f$ is a tangent to the curve at any other point h, making an angle θ_1 with the horizontal semichord $h\ d$.

Fig. 3.



$\theta\ \theta_1$ are called angles of direction. Let it be required to draw a tangent to the curve at any point h; from h draw the horizontal chord $h\ i$; and from the centre of this chord line let fall the perpendicular $d\ f$; make $d\ f$ twice the deflection $d\ e$, and join $h\ f$; then $h\ f$ will be the tangent, and $f\ h\ d$ will be the angle of direction. As sin. θ and tan. θ will be required, we will give formulæ for finding them before proceeding further.

Let d = the greatest deflection.
s = the semichord.

Then, $\text{Tan. } \theta = \frac{2d}{s}$ $\text{Sin. } \theta = \frac{2d}{\sqrt{(2d)^2+s^2}}$

To find the tension on the chain,

Let W = half the total load.
T = tension at point of support.
t = lowest point in chain.
θ = the angle of direction at point of support.

Then $T = \frac{W}{\text{sin. } \theta}$, and $t = \frac{W}{\text{tan. } \theta}$.

Let L = span of chains.

Then substituting the values of the tangent and sine,

$$T = \frac{W\sqrt{s^2+4d^2}}{2d} \qquad t = \frac{W\,L}{4d}$$

(To be Continued.)

MECHANICS, PHYSICS, AND CHEMISTRY.

On a Regenerative Gas Furnace, as applied to Glass-houses, Puddling, Heating, &c. By Mr. C. William Siemens, of London.

From Newton's London Journal, August, 1862.

The arrangement of furnaces about to be described, is applicable with the greatest advantage in cases where great heat has to be maintained; as in melting and refining glass, steel, and metallic ores, in puddling and welding iron, and in heating gas and zinc retorts, &c. The fuel employed, which may be of very inferior description, is separately converted into a crude gas, which, in being conducted to the furnace, has its naturally low heating power greatly increased by being heated to nearly the high temperature of the furnace itself, ranging to above 3000° Fahr.; undergoing at the same time certain chemical changes, whereby the heat developed in its subsequent combustion is increased. The heating effect produced is still further augmented by the air necessary for combustion being also heated separately to the same high degree of temperature, before mixing with the heated gas in the combustion chamber or furnace; and the latter is thus filled with a pure and gentle flame of equal intensity throughout the whole chamber. The heat imparted to the gas and air before mixing is obtained from the products of combustion, which, after leaving the furnace, are reduced to a temperature frequently not exceeding 250° F. on reaching the chimney; thereby effecting great economy in fuel, with other advantages.

The transfer of heat from the products of combustion to the air and gas entering the furnace, is effected by means of regenerators, the principle of which has been recognised to some extent since the early

part of the present century, but has not hitherto been carried out in any useful application in the arts, unless the respirator invented by Dr. Jeffreys be so considered. The discovery of this principle is ascribed to Rev. Mr. Stirling, of Dundee, who, in conjunction with his brother, James Stirling, attempted as early as the year 1817 to apply it to the construction of a hot-air engine: their engine did not, however, succeed, nor did Captain Ericsson's later attempts in the same direction lead to more satisfactory results. The economical principle of the regenerator having attracted the writer's attention in 1846, he constructed in the following year an engine in which superheated steam was used in conjunction with the regenerator; many practical difficulties, however, prevented a realization of the success which theory and experiments appeared to promise; but it is gratifying to find that one principle then adopted—that of superheating the steam—has since received the sanction of an extended application.

The employment of regenerators for getting up a high degree of heat in furnaces, was suggested in 1857 by the writer's brother, Mr. Frederick Siemens, and has since been worked out by them conjointly through the several stages of progressive improvement. The results obtained by the earlier applications of the principle were communicated by the writer in a paper read at a former meeting of the Institution, and two or three of the furnaces then described, employed for heating bars of steel, still remain in operation. In attempting, however, to apply the principle to puddling, and other larger furnaces, serious practical difficulties arose, which, for a considerable time, frustrated all efforts; until, by adopting the plan of volatilizing the solid fluid in the first instance, and employing it entirely in a gaseous form for heating purposes, practical results were at length obtained, surpassing even the sanguine expectations previously formed.

In the early form of the regenerative heating furnace, which has been in continuous work during the last three years for heating bars of steel at Messrs. Marriott and Atkinson's Steel Works, Sheffield, and also at the Broughton Copper Works, Manchester, there is a single fireplace, containing a ridge of fuel, fed from the top, and two heating chambers, in which the bars of metal to be heated are laid with a regenerator at the end of each chamber, by which the waste heat passing off from the furnace is intercepted on its way to the chimney, and transferred to the air entering the furnace. Each regenerator is composed of a mass of open fire-bricks, exposing a large surface for the absorption of heat, through which the products of combustion are made to pass from the furnace, and are thus gradually deprived of nearly all their heat previous to escaping into the chimney. The end of the regenerator nearest the furnace becomes gradually heated to nearly the temperature of the furnace itself, while the other end nearest the chimney remains comparatively cool. The direction of the draft being now reversed by means of a valve, the air entering the furnace is made to pass through the heated regenerator in the contrary direction, encountering first the cooler portions of the brickwork, and acquiring successive additions of heat in passing through

the regenerator, until it issues into the first chamber of the furnace at a very high temperature, and, traversing the ridge of fuel, produces a flame which fills the second heating chamber; whence the products of combustion passing through the second cold regenerator deposit their heat successively in the inverse manner, reaching the chimney comparatively cool. By thus alternating the current through the two regenerators, a high degree of temperature is maintained constantly in the furnace. This arrangement of furnace is evidently applicable only in exceptional cases where two chambers are to be heated alternately, nor does it admit of being carried out upon a large scale.

In heating a single chamber the expedient was resorted to of providing two fireplaces, to be traversed in succession by the heated air, with the heating chamber placed between. Here the difficulty arose that the air, the oxygen of which was already combined with carbon (forming carbonic acid) in traversing the first fireplace, took up a second equivalent of carbon (forming carbonic oxide) in traversing the second, so that the fuel of the second fire was consumed to no purpose. In order to diminish this loss, and also avoid impairing the draft by a double resistance, the ridges of fuel were discontinued, and the coal was fed into the furnace from the sides resting on a solid hearth, to be there volatilized by the heated air passing over it. By frequently stirring the first fire, its combustion was favored until the current was reversed, when it was left undisturbed until the next change, and so on alternately. It was found very difficult, however, to maintain an active and uniform combustion, and to burn the purely carbonaceous substance that was left in the fireplace after the gaseous portion of the fuel had been volatilized; and it had frequently to be raked out in order to make room for fresh gaseous fuel. This circumstance led to the first step towards the employment of fuel in the form of gas, by providing a small grate below the heap of fuel, through which a gentle current of air was allowed to enter, forming carbonic oxide, which afterwards further combined with oxygen on meeting with the hot current of air entering the furnace from the regenerator. The two fireplaces of alternating activity were, however, attended with considerable practical inconvenience; the furnacemen, in particular, disliked the idea of attending two fireplaces instead of one, and being little interested in the saving of fuel, took no pains to work the furnace in a satisfactory manner.

It therefore became necessary to devise a plan of heating a single chamber continuously by one fireplace, in combination with the alternate reversal of currents through the regenerators, but without reversing the direction of the flame. This was accomplished by means of double reversing valves, and was practically carried out in a puddling furnace that worked for a considerable length of time at the ironworks of Messrs. R. and W. Johnson, near Manchester.

There still remained drawbacks, however, which prevented an extensive application of this form of furnace: the fire required frequent attention, and it was difficult to maintain a uniform volume of flame in the furnace; the reversing valve at the hot end of the regenerators

was, moreover, liable to get out of order, and the furnace was costly to erect.

The most important step in the development of the regenerative furnace, has been the complete separation of the fireplace or gas producer from the heating chamber or furnace itself. When a uniform and sufficient supply of combustible gas is insured, it can evidently be heated just like the air, by being passed through a separate regenerator before reaching the furnace, whereby its heating power is greatly increased. The difficulty of maintaining a uniform flame in the furnace is thereby certainly removed, and there is no longer any necessity for keeping the flame always in the same direction through the furnace, since the gas can be introduced with equal facility at each end of the heating chamber in turn, and the periodical change of direction of the flame through the furnace tends only to make the heat more uniform throughout. The new plan of a separate gas producer has now been successfully carried out in practice, and there are already a considerable number of the regenerative gas furnaces in satisfactory operation in this country and on the continent applied to glass-houses, iron furnaces, &c. In the neighborhood of Birmingham, at Messrs. Lloyd and Summerfield's glass works, a flint glass furnace, constructed upon this plan, has now been in continuous operation for nearly twelve months, and affords a good opportunity for ascertaining the consumption of fuel of the regenerative furnace as compared with the previous furnace performing the same work. At the glass works of Messrs. Chance, Brothers, & Co., near Birmingham, the regenerative gas furnace has been under trial for the same length of time, and has latterly been adopted for the various purposes in crown and sheet glass making upon a very large scale. Messrs. James Russell & Sons, Crown Tube Works, Wednesbury, are also applying the furnace to the delicate operation of welding iron tubes. Another flint glass furnace, erected by Messrs. Osler in Birmingham, and several puddling furnaces erected by Messrs. Gibbs Brothers, at Deepfields, and by Mr. Richard Smith, at the Round Oak Iron Works, are amongst the latest applications of the regenerative gas furnace, the designs having in all cases been furnished by the writer, and carried out under his brother's immediate superintendence.

The gas producers are entirely separate from the furnace where the heat is required, and are made sufficient in number and capacity to supply several furnaces. The fuel is supplied at intervals of from six to eight hours through covered holes, and descends gradually on an inclined plane, set at an inclination of from 45° to 60°, according to the nature of the fuel used. The upper portion of the incline is made solid, being formed of iron plates covered with fire-brick; but the lower portion is an open grate formed of horizontal flat steps. At the foot of the grate is a covered water trough, filled with water up to a constant level from a small feeding cistern, supplied by a water pipe with a ball tap. Below the water trough is an opening for drawing out clinkers, which generally collect at that point. Small stoppered holes are provided at the top of the producer, to allow of putting in an

iron bar occasionally to break up the mass of fuel and detach clinkers from the side walls. Each producer is made large enough to hold about ten tons of fuel in a low incandescent state, and is capable of converting about two tons of it daily into a combustible gas, which passes off into a gas flue leading to the furnace.

The action of the gas producer in working is as follows:—The fuel descending slowly on the solid portion of the inclined plane, becomes heated, and parts with its volatile constituents, the hydro-carbon gases, water, ammonia, and some carbonic acid, which are the same as would be evolved from it in a gas retort. There now remains from 60 to 70 per cent. of purely carbonaceous matter to be disposed of, which is accomplished by the slow current of air entering through the grate, producing regular combustion immediately upon the grate; but the carbonic acid thereby produced, having to pass slowly on through a layer of incandescent fuel, from 3 to 4 feet thick, takes up another equivalent of carbon, and the carbonic oxide thus formed passes off with the other combustible gases to the furnace. For every cubic foot of combustible carbonic oxide thus produced, two cubic feet of incombustible nitrogen pass also through the grate, tending greatly to diminish the richness or heating power of the gas. Not all the carbonaceous portion of the fuel is, however, volatilized on such disadvantageous terms; for the water trough at the foot of the grate, absorbing the spare heat from the fire, emits steam through small holes, under the lid; and each cubic foot of steam, in traversing the layer of from three to four feet of incandescent fuel, is decomposed into a mixture consisting of one cubic foot of hydrogen and nearly an equal volume of carbonic oxide, with a variable small proportion of carbonic acid. Thus, one cubic foot of steam yields as much inflammable gas as five cubic feet of atmospheric air; but the one operation is dependent upon the other, inasmuch as the passage of air through the fire is attended with the generation of heat, whereas the production of the water gases, as well as the evolution of the hydro-carbons, is carried on at the expense of heat. The generation of steam in the water trough being dependent on the amount of heat in the fire, regulates itself naturally to the requirements; and the total production of combustible gases varies with the admission of air; and since the admission of air into the grate depends, in its turn, upon the withdrawal of gases evolved in the producer, the production of the gases is entirely regulated by the demand for them.

In order to deliver the gas into the furnace without depending upon a chimney draft for that purpose, the following plan has been adopted: The mixture of gases, on leaving the producers, has a temperature ranging between 300° and 400° Fahr., which must, under all circumstances, be sacrificed, since it makes no difference to the result at what temperature the gas to be heated enters the regenerators; the final temperature being in all cases very nearly that of the heated chamber of the furnace, or say, 2500° Fahr. The initial heat of the gas is, therefore, made available for producing a plenum of pressure by making the gas rise about 20 feet above the producers, then carry-

ing it through a horizontal tube 20 or 30 feet long, and letting it again descend to the furnace. The horizontal tube, being exposed to the atmosphere, causes the gas to lose from 100° to 150° of temperature, which increases its density from 15 to 20 per cent., and gives a preponderating weight to that extent to the descending column, urging it forwards into the furnace.

The author then described the application of the regenerative gas furnace to a melting furnace in course of erection at the British Plate Glass Works, near St. Helen's. This furnace was selected because of its improved details of construction. The heating chamber of the furnace contains twelve glass pots, which are got out through the side doors when the glass is ready for casting upon the moulding table. Underneath are placed transversely four regenerators, composed of open fire-bricks built up on a grating: they are arched over at top, and support the bed or siege of the furnace. The regenerators work in pairs—the two under the right-hand end of the siege, communicating with that end of the heating chamber, while the other two communicate with the opposite end. The gas enters the chamber through three passages, and the air through two intermediate passages, whereby they are kept entirely separate up to the moment of entering the furnace, but are then able immediately to mingle intimately, producing at once an intense and uniform flame in the heating chamber. The siege is built of fire-brick, with a number of transverse channels, through which the cold entering air is made to pass on its way into the air flue. By this means, the siege is kept comparatively cool, so that no fluid glass can pass through crevices into the regenerators. Any melted glass that may fall from the heating chamber through the apertures at the ends of the siege does not get into the regenerators, but falls into pockets, whence it can be removed through openings in the side walls. The passage by which the air enters affords the means of getting at the regenerators through an opening at the end of each.

From the air flue, the entering air is directed by a reversing valve into the air regenerator, and there becomes heated, ready for entering the furnace; at the same time, the gas entering from the gas flue is directed by a reversing valve into the gas regenerator, where it becomes heated to the same temperature as the air. Similarly, the products of combustion, on leaving the opposite end of the furnace, pass down through the second pair of regenerators, and, after being here deprived of their heat, are directed by the reversing valves into the chimney flue. When the second pair of regenerators have become considerably heated by the passage of the hot products of combustion, and the first pair correspondingly cooled by the entering air and gas, the valves are reversed, and the currents caused to pass through the regenerators and the heating chamber in the contrary direction; whereby the hot pair of regenerators is now made use of for heating the gas and air entering the furnace, while the cool pair abstracts the heat from the products of combustion escaping from the furnace. The supply of air and gas to the furnace is regulated by adjustable stop valves, whereby

the nature and volume of the flame in the furnace may be varied at pleasure; whilst the chimney damper is used to regulate the amount of pressure in the furnace in relation to the atmosphere, so as to allow the opening of working holes.

In setting out each individual furnace, the heating effect required, the quality of the fuel employed, and the particular nature of the process to be performed, have to be considered. The amount of heat required determines the capacity of the regenerators: and the gas regenerators require fully as large a capacity as the air regenerators, and sometimes even a greater. This would, perhaps, hardly be expected, but will be seen to be the case from the following considerations: The gases proceeding from the gas producers are a mixture of olefiant gas, marsh gas, vapor of tar, water and ammoniacal compounds, hydrogen gas, and carbonic oxide; besides nitrogen, carbonic acid, some sulphuretted hydrogen, and some bi-sulphuret of carbon. The specific gravity of this mixture averages 0·78, that of air being 1·00; and a ton of fuel, not including the earthy remnants, produces, according to calculation, nearly 64,000 cubic feet of gas. By heating these gases to 3000° Fahr., their volume would be fully six times increased, but, in reality, a much larger increase of volume ensues, in consequence of some important chemical changes effected at the same time. The olefiant gas and tar vapor are well known to deposit carbon on being heated to redness, which is immediately taken up by the carbonic acid and vapor of water—the former being converted into carbonic oxide, and the latter into carbonic oxide and pure hydrogen. The ammoniacal vapors and sulphuretted hydrogen are also decomposed, and permanently elastic gases, with a preponderance of hydrogen, are formed. The specific gravity of the mixture is reduced, in consequence of these transformations, to 0·70, showing an increase of volume from 64,000 to nearly 72,000 cubic feet per ton of fuel, taken at the same temperature. This chemical change represents a large absorption of heat from the regenerator, but the heat is given out again by combustion in the furnace, enhancing the heating power of the fuel beyond the increase due to elevation of temperature alone.

The advantages of the regenerative gas furnace are of equal value in the case of puddling and welding iron. In a puddling furnace constructed on this plan, the four regenerators are arranged longitudinally underneath the puddling chamber, which may be of the usual form. In order to complete the combustion of the gas and air in passing through the comparatively short length of the puddling chamber, it is necessary to mix them more intimately than is requisite in the large glass furnaces. For this purpose, a mixing chamber is provided at each end of the puddling chamber, and the gas and air from the regenerators are made to enter the mixing chamber from opposite sides; the gas aperture is, moreover, placed several inches lower than the air aperture, so that the lighter stream of gas rises through the stream of air, while both are urged forward into the puddling chamber, and an intense and perfect combustion is produced. The mixing chambers are sloped towards the furnace, in order to drain them of any cinders

which may get over the bridge. The reversal of the current through the furnace is effected about every hour, by reversing valves in the air and gas flues, the arrangement of which is exactly similar to that already described in the glass furnace: the supply of gas and air is regulated by throttle valves, and the draft through the furnace by the ordinary chimney damper.

The same arrangement, with obvious modifications, may be applied also to blooming and heating furnaces, the advantages in both cases being a decided saving of iron, besides an important saving in the quantity and quality of the fuel employed. The space saved near the hammer and rolls by doing away with fireplaces, separate chimney stacks, and stores of fuel, is also a considerable advantage in favor of the regenerative gas furnace in ironworks. The facility which it affords for either concentrating the heating effect, or diffusing it equally over a long chamber, by effecting a more or less rapid mixture of the air and gas, renders the furnace particularly applicable for heating large and irregular forgings, or long strips or tubes, which have to be brought to a welding heat throughout. It has already been applied to a considerable extent in Germany, for heating iron; having been worked out there under the direction of the writer's eldest brother, Dr. Werner Siemens, who has also contributed essentially to the development of the system. The furnaces at the extensive iron and engine works of M. Borsig, of Berlin, are being remodelled for the adoption of this system of heating, as have also been those at the imperial factories at Warsaw.

Another important application of the regenerative gas furnace is as a steel melting furnace, in which the highest degree of heat known in the arts is required—presenting, consequently, the greatest margin for saving of fuel. This application of the regenerative gas furnace is rapidly extending in Germany, but has not yet practically succeeded in Sheffield, where it was also tried: it is, however, in course of application at the Brades Steel Works, near Birmingham.

Other applications of the regenerative gas furnace are being carried out at the present time; among which may be mentioned one to brick and pottery kilns, for Mr. Humphrey Chamberlain, near Southampton; for Messrs. Cliff, of Wortley, near Leeds; and for Mr. Cliff, of the Imperial Potteries, Lambeth; also to the heating of gas retorts at the Paris General Gas Works, and at the Chartered Gas Company's Works, London. The description already given, however, is sufficient to show the facility with which this mode of heating may be adapted to the various circumstances under which furnaces are employed. The important application of the regenerative system to hot-blast stoves for blast furnaces, by Mr. E. A. Cowper, has already been communicated to the Institution.

The experience hitherto obtained with the regenerative mode of heating, shows that it is attended with the greatest proportionate advantage in localities where good coal is scarce, but where an inferior fuel abounds. This applies most forcibly to the South Staffordshire district, where the best coal, in lumps, is worth 12s. 6d. per ton,

whereas good slack can be had at 3s. or 4s. per ton. The question gains, moreover, in importance when it is considered that, according to the best authorities, the thick coal of the district is coming to an end, while millions of tons of coal dust have accumulated, of no present commercial value, which, on being converted into gas in the manner described, by means of the gas producers, would acquire a heating value equal, at any rate, to the same weight of the best coal, in the manner in which it is at present used. Considering also the proximity of the pits to the ironworks in this district, it may be suggested, whether the gas producers, being of very simple construction, might not with advantage be placed near the banks of fuel, above or even under ground—the gas being conveyed to the works by a culvert, so as to supersede carting of the fuel. Such an arrangement might notably contribute to perpetuate the high position which South Staffordshire has so long maintained as an iron producing district.

Proceedings Insti. Mech. Engineers, June 30, 1862.

Rudders for Steering Ships under Steam.

From the Lond. Mechanics' Magazine, July, 1862.

An interesting trial recently took place at Portsmouth of a plan, patented by Captain Warren, R. N., for steering ships under steam by a rudder placed in the vessel's bow. The chief merits claimed by Captain Warren for his patented rudder are, that it is an auxiliary steering power to the ordinary rudder, assisting the ship to turn quicker when necessary, as might be the case under the fire of an enemy's battery, and also that it should replace the ordinary rudder in the event of any accident happening to the latter, either from the weather or the shot of the enemy. The vessel with which the principle was tested was the *Princess Royal*, a small paddle steamer belonging to the Portsmouth and Isle of Wight Steam Packet Company, and to the bows of which a rudder had been temporarily fitted. The rudder had, however, an area of only nine feet, or one-third that of the vessel's ordinary rudder aft. It was also evidently placed too far forward, and was not sufficiently immersed, the upper part of the rudder being some nine inches above the water line. In fitting a bow rudder to a man-of-war, Captain Warren proposes to have the upper part of the rudder 15 feet below the water line in a vessel drawing, like Her Majesty's ship *Defence*, 26 feet of water, and other ships in proportion. It is evident, therefore, that the principle, although certain favorable results were obtained, could not be fairly tested; that is, that with an increased area and submersion of the rudder, and an alteration of position, its power would have been more fully developed. Capt. Broadhead, R. N., conducted the trials. Among the gentlemen on board to witness the trial were Admiral Sir H. D. Chads, Captain Fullerton, R. N., Mr. A. Heather, manager of the United Steam Packet Company; Mr. Reed, manager of Messrs. White's ship-building yard and slipway, &c.

The first trial was made by placing the after or ordinary rudder of the ship hard over, when the ship made a complete circle in 3 minutes 22 seconds, the engines making 27 revolutions. In the second trial the forward rudder was put hard over; but the vessel was so long in making the half-circle that this trial was abandoned. In the third trial the forward rudder was put hard over, and the after rudder fixed amidships with chocks, when a circle was completed to port in 6 min. 19 sec., the engines making 26½ revolutions. In the fourth, the forward rudder was again put hard over, but this time with the after rudder loose, when the time occupied in completing the circle, the steamer coming round in this instance also to port, was 8 min. 24 sec., the revolutions of the engines being 26½. In the next trial the after rudder was put hard over, with the forward rudder loose, and the ship made the circle to port in 3 minutes, the revolutions of the engines being 26. Both rudders were next put hard over together, when a circle was completed to port in 2 min. 47 sec., a gain of 13 sec. on the preceding trial, the engines making 24 revolutions. When the ship stopped dead, the after rudder was put hard over and forward rudder fixed, when the engines were turned ahead, the time being taken from their moving fairly ahead. Circle completed in 3 min. 37 sec. The same experiment was next carried out with the forward rudder, when the circle to port was completed in 6 min. 40 sec., the revolutions of the engines being 25½. Forward rudders, like screws, require lengthened and expensive experiments to develop their powers, and are almost beyond the means of private individuals. There is, however, no doubt, considerable merit attached to the plan proposed by Captain Warren, but the experiments require to be carried out on a larger and more perfect scale.

Consumption of Soap.

From the Lond. Builder, No. 956.

In an address delivered by the engineer of the Glasgow Water Works, that gentleman remarked, that Mr. Porter estimates the annual consumption of soap at 9·2 lbs. per individual. The total population of Glasgow may be taken at 460,000; deduct for Gorbals, 110,000; total on the north of the river, 350,000. Supposing that only 5½ lbs. of soap is allowed for each person, it will give £72,000 as the annual cost of soap, on the average of the country, consumed by the 350,000 persons, on the north of the Clyde. Since the introduction of Loch Katrine, owing to its softness, careful returns show that nearly one-half of the soap formerly used will now suffice. If these calculations were applied to London, the saving there, allowing for the harder character of the water, would amount to not less than £400,000 per annum, equivalent to the interest of *ten millions of money*, which it would be worth the while of the Londoners to pay for water equal in quality to that of Loch Katrine.

A Lecture by Dr. W. Odling, F.R.S., *on* Mr. Graham's *Researches in Dialysis*. Delivered at the Royal Institution Feb. 14, 1862.

From the Lond. Chemical News, No. 120.

(Continued from p. 187).

We now come to consider this property of diffusibility, as to whether or not it bears any definite relation to the other properties of bodies. Can we, from knowing the chemical or physical constitution of a body, predicate its diffusibility? Is, in fact, its diffusibility associated with any definite chemical or physical property which it possesses? Well, it certainly does not seem to be associated with chemical constitution in any way, as we find, for instance, whether we perform the experiment by means of jar or vial diffusion, that sugar, which is a very complex organic body, has much the same diffusibility as sulphate of magnesia, which is a simple mineral salt. It is also found that picric acid, which is very complex in its constitution, has almost the same diffusive power as common salt, which belongs to the most simple series of salts with which chemists are acquainted. We do find, however, that bodies which are isomorphous in form have much the same diffusibility; but that groups of equi-diffusive substances are much larger than those of isomorphous compounds. Take the common salt group, for instance; chloride of sodium, bromide of sodium, and iodide of sodium, which have a similar chemical composition, and are isomorphous in form, have a similar diffusibility; but nitrate of soda, which is dissimilar in composition, and heteromorphous in form, is nevertheless equi-diffusive with the members of the common salt group.

Going a little further, however, we find that although it is difficult to predicate of saline substances, which shall be the most diffusive, yet if we compare highly diffusive substances, such as salt, and sugar, and sulphate of magnesia, with feebly diffusive substances, such as albumen and gum, and caramel and tannin, one broad distinction becomes apparent, which is, that bodies which are readily crystallizable are also readily diffusible; whereas bodies which ordinarily exist in the amorphous state, and which, more especially, are characterized by their property of forming gelatinous hydrates,—such substances, for instance, as jelly and gum, and caramel,—are feebly diffusive; and this has led Mr. Graham to establish a distinction between bodies which differ thus from one another. They are divided by him into two classes,—crystalloids, or highly diffusive bodies, on the one hand, and colloids, or gelatigenous or feebly diffusive bodies, on the other. I shall have occasion to refer more particularly to the distinctions between crystalloids and colloids further on.

We have next to consider what is the nature of the diffusive action. What is the nature of the force which impels the particles of salt, for instance, to spread themselves out among the particles of liquid? Of course, we may attribute the action to a self-repulsion of the particles of the salt, on the one hand, and of the particles of the water, on the other; or, if we please, we may attribute it to a kind of attraction ex-

isting between the particles of the salt and the particles of the water—a mutual attraction of the particles of the water for those of the salt, and of the particles of salt for those of the water; and, simply for the sake of explaining and colligating our phenomena, we will assume this latter hypothesis; for I do not suppose that by attributing the action either to self-repulsion or mutual attraction, I am really doing anything towards explaining the causation of the phenomena. We will, then, assume diffusion to be an attraction of the particles of the salt for the particles of the water. On this understanding, then, we must say that the particles of a crystalloid have a much greater attraction for the particles of water than have the particles of a colloid substance. Now, if a salt really has this superior attraction for molecules of water, we can understand how it may be not only able to unite diffusively with free water, but also with water that is in a low form of combination as it exists in a soft solid, for instance, such as jelly. Jelly is a substance which contains no free water, no liquid water; the whole of the water existing in it is in a state of combination. The substance is a soft solid, not necessarily wet, for it does not wet the hand. Now, a crystalloid body, such as common salt, can not only unite diffusively with free water, but it can also unite diffusively with water that is already in a state of loose combination in the form of a soft solid. Here is an experiment made in a precisely similar manner to our experiment on jar diffusion, except that the diffusion of chloride of copper in this instance, instead of being allowed to take place into free water, is allowed to take place into a soft solid. This is a jelly made of Japanese gelose; and here, you see, we have a diffusion of the green chloride of copper taking place into the mass of jelly precisely as it did into the water. The table shows the diffusion of chloride of sodium into gelose; here are the results. Without going into all the details there given, I may say this much, that the diffusion of common salt into this substance, gelose, is almost as great as into free water. At any rate, the diffusion of common salt into gelose in eight days is greater than the diffusion of common salt into water in seven days. But although the introduction of gelose, or a gelatinous substance, does not interfere in any appreciable way with the diffusion of a crystalloid body, it arrests almost completely the diffusion of a colloid body. A colloid body has very little tendency to unite diffusively, even with free water, and is quite incapable of uniting diffusively with water in any kind of combination, however feeble.

We have already seen, that by diffusion into water we may effect the partial separation of a highly diffusive substance, such as common salt, from a feebly diffusive substance, such as albumen; but we may effect a much more complete separation if, instead of using water, we cause the diffusion to take place into or through a soft solid; for such a substance, as I have said, scarcely impedes the diffusion of the crystalloid, but almost arrests the diffusion of a colloid. For instance, if we have a soft solid, such as a piece of vellum, or a piece of animal membrane, on a layer of mucus, interposed between a colloid solution and a quantity of water, the colloid, in order to get into the water,

must pass through the membrane,—must unite diffusively with the combined water of the membrane itself, and that it is incapable of doing. A crystalline body can pass through, and a colloid body cannot. Now, this constitutes dialysis. Dialysis is the separation of a crystallized body from a colloid body through a membrane which will allow the crystalloid to pass through, but will not allow the colloid, because the crystalloid has a strong power of uniting diffusively with water, whereas the colloid has a very feeble power. The crystalloid can unite diffusively with the water that is in combination with the soft solid septum, so as to reach the external water, but the colloid cannot.

We will now refer to the experiment with which we began the lecture. Into this dialyzer we introduced some magenta, which is a crystalline body, and you perceive that a diffusion through the membrane into the external water has taken place to a very considerable extent. Into this [calling attention to the second jar] we introduced the red coloring matter of blood, and here there is not the least evidence whatever that any color has passed through. Those who are sitting on my left hand may perhaps see an apparent coloration, which arises from the coloring matter contained in these two other jars which are standing near being seen through; but not the least shade of coloring matter has really passed through the membrane in this instance. Now, in in this case [referring to the third dialyzer which had been charged at the commencement of the discourse] we took a mixture of the red crystalline body, magenta, and the brown colloid or non-diffusible body, caramel; and you will find that whereas there is no browning whatever of the liquid in the jar, a considerable quantity of the crystalline body has already passed through the dialyzer and will continue to pass through. The membrane arrests the caramel and allows the magenta to pass.

I want to impress upon you that this process of dialysis is altogether different from filtration. Filtration refers to the passage of masses through appreciable pores. Here there are no pores. The phenomena of dialysis are not molar, but molecular. I may be able to show you that, by a very simple contrivance which we have here. Two small gas jars have been fitted up, one as a dialyzer, with an impervious septum,—impervious to the passage of liquid mechanically; the other with a septum of filtering paper. In this last case only, we shall get filtration. We will first pour a little liquid into this colloid septum, and on passing the hand beneath it we find it perfectly dry; there is no water passing through. The membrane, as a mere membrane, is impervious to the passage of liquid. It will allow chemical action to take place, or that low form of chemical action which we have spoken of as diffusion, but it will not allow of filtration. Now, this one [the other small jar] is covered with thick filtering paper, and we will pour the water into it in a similar manner, and you see in this case we have filtration, or a mechanical passage of masses of water through the pores of the paper; whereas in this case [referring to the former] there is no passage whatever.

I would here direct your attention for a few moments to some of

the results of dialysis. This [pointing to the table given below] represents the dialysis through parchment-paper for twenty-four hours, of 10 per cent. solutions of the different substances shown in the first column:—

	Grammes diffused.
Gum arabic,	0·029
Starch sugar,	2·000
Cane sugar,	1·607
Milk sugar,	1·387
Mannite,	2·621
Glycerine,	3·330
Alcohol,	3·570
Starch sugar (second experiment),	2·130
Chloride of sodium,	7·500

These experiments were made in the order shown, with one and the same dialyzer, which was constructed in this manner [referring to a gas-jar dialyzer on the lecture table]. After each experiment the dialyzer was put into water for some time, and the septum thoroughly washed. You see from the table that gum arabic scarcely diffused at all—at any rate, it yielded less than $\frac{3}{100}$ths of a gramme of diffusate, while under precisely the same conditions, the starch sugar yielded exactly two grammes of diffusate. The quantity of cane sugar that passed through was rather less than that of the starch sugar; of the milk sugar, rather less than of the cane sugar; of the mannite again, rather more, and of the glycerine and alcohol still more. And now the experiment was repeated with starch sugar, in order to see whether any alteration had taken place in the septum of parchment-paper through which all these dialyses had taken place, and you perceive that practically there was no alteration in the result. Then, chloride of sodium was employed, from the ten per cent. solution of which $7\frac{1}{2}$ grammes of salt diffused, showing how much more readily that body passed through than did the gum arabic and the substances previously experimented upon. Other dialytic septa than parchment-paper may be employed, a layer of mucus spread between two folds of calico for instance, with scarcely any difference in the relative diffusibilities being manifested.

We will now turn our attention to some of the various colloid bodies which Mr. Graham has succeeded in preparing by dialysis, and some of his results are really most extraordinary—most wonderful. Here is a substance existing obviously in the crystalline form, viz: quartz or silica. But this body, in common with very many others, is capable of existing in the colloid as well as in the crystalloid form, as we shall presently see. Now, chemists by means of strong alkalies and acids are capable of getting this quartz into solution, and have been for many years past; but Mr. Graham has shown us how to obtain a solution which contains nothing but quartz and water. He took silicate of soda, a soluble crystalline salt, made by fusing quartz with carbonate of soda at a red heat, which, in common with other crystalloids, diffuses very readily. He acidified the aqueous solution of this salt with hydrochloric acid, whereby the state of the constituent silica

was changed from the crystalloid into the colloidal. The acidified solution was then placed on a dialyzer, which was floated on a basin of water, and, after 24 hours, 36 per cent. of the hydrochloric acid had passed through, while, after four days, not a trace of either hydrochloric acid or chloride of sodium was left. Nothing but silica and water remained on the dialyzer—nothing but an aqueous solution of this hard substance, quartz. Here is some of the liquid so obtained, the solution of sand in water. The colloidal silica procured in this way, or co-silicic acid as it has been termed by Mr. Graham, affords a very good illustration of the properties of colloidal bodies in general, of their non-crystalline habit, of their low diffusibility, of their chemical inertness and high atomicity, and above all, of their mutability. The 5 per cent. solution of silica obtained at once by dialysis, is quite transparent and mobile. It may be boiled in a flask and considerably concentrated without undergoing any obvious change; and even a 14 per cent. solution is perfectly limpid. But aqueous co-silicic acid, in common with all colloidal solutions, after a longer or shorter time, according to its purity and dilution, undergoes a spontaneous change. It becomes at first opalescent and viscous, and eventually sets into a firm, insoluble jelly. Hence, Mr. Graham speaks of two colloidal states, the peptous, or dissolved, and the pectous, or gelatinized. The jelly of silica gradually shrinks and exudes pure water. When dried *in vacuo* over oil of vitriol at ordinary temperatures, it forms a lustrous, transparent, glassy mass, which, however, is not anhydrous. The residue left by its ignition has a specific gravity of 2·2, that of crystalline silicic acid being 2·6. It seems probable that the colloid may become gradually changed into the crystalloid form of silica. The pectization of a solution of co-silicic acid may be produced at will. When the liquid is boiled, for instance, in an *open* vessel, a ring of insoluble silica forms round the margin of the liquid and causes the whole to gelatinize. Again, pectization is effected in a very short time by the addition of a solution containing even one-ten thousandth of any alkaline or earthy carbonate. I have here a solution of colloid silicic acid, that is, a solution of metamorphosed sand in water. I now add to it a little carbonate of potash solution, and in performing the experiment here, upon a large scale, I will add an excess of the carbonate in order to accelerate the action. The liquid is at present gelatinizing perceptibly. We will leave it quiet for a few moments, and you will then see what an alteration has taken place in its character. Now, our jelly is formed. If I were to give it a little more time it would set more firmly, but as it is, I shall be able to show you, by inverting the flask, that the contents are no longer liquid, but gelatinous. [The flask containing the gelatinized silica was here inverted without any spilling of its contents.]

In its chemical relations the solution of co-silicic acid, in common with other colloid liquids, is characterized by its inertness. It does not manifest any decided chemical properties, and its re-actions, such as they are, take place very slowly. It enters into its combinations, moreover, with a very high atomic weight, so as to form a very high

per centage of the compounds which it forms. Thus, its solution when tested with delicate litmus paper shows but a very feeble acidity, not greater than that of carbonic acid water. When placed in the mouth it is at first quite tasteless, and we can readily understand why this should be—for the substance being colloidal, cannot dialyze through the colloid membrane of the tongue so as to affect the gustatory nerves. But although quite tasteless at first, it produces, after some time, a sort of acrid feeling in the mouth, owing, doubtless, to some alteration in the state of the silica. The acid re-action of 100 parts of dissolved co-silicic acid is neutralized by 1·8 parts of anhydrous potash, and by corresponding quantities of soda and ammonia. When added to an excess of lime water, co-silicic acid produced a gelatinous precipitate containing 6 per cent. of the base. These co-silicates are, however, very variable in their composition and very unstable. Co-silicic acid, moreover, gives precipitates with several colloid solutions, those of alumina, peroxide of iron, gelatine, and albumen, for instance. Its action on gelatine closely resembles that of tannin, which is a similar colloid acid. Thus, a piece of skin immersed in a weak solution of co-silicic acid becomes after a time thoroughly tanned or converted into leather; and the process of tanning with co-silicic acid further resembles that of common tanning in the very gradual manner in which the combination takes place, and in the indefinite character of the compound produced. But my time is getting on so rapidly that I must not devote any more of it to silica. Here, however, is another of these colloid solutions to which I should like to direct your attention for a few moments, because it is the newest of them all. In Mr. Graham's paper in the *Philosophical Transactions*, he observes, that though he was able to obtain stannic acid, the analogue of silicic acid, in the colloidal state, he could only get it in the pectous, not in the soluble, form of the colloidal state. Precipitated peroxide of tin or stannic acid, though insoluble in water, is readily soluble in a solution of bi-chloride of tin; when the liquid so produced is submitted to dialysis the whole of the chlorine passes away, but a jelly instead of a solution of stannic acid is left on the dialyzer. But Mr. Graham has since found that by acting upon this jelly with a dilute alkali, and then submitting it to a further dialysis, it gradually becomes liquid. This last process he terms peptizing, or digesting. Here then we have a solution of co-stannic acid, which has been obtained by peptization, and which we can now very readily pectize by adding a minute quantity of hydrochloric acid. Here you see we get the pectization. The whole liquid is becoming perfectly gelatinous, and this soft amorphous form of stannic acid contrasts remarkably with the hard crystalline native tin-stone which I hold in my hand.

I will next bring under your notice the aqueous solution of colloidal peroxide of iron. This oxide, in the native form, is known as hæmatite, a specimen of which I have here before you. Now, this oxide, under ordinary circumstances, is quite insoluble in water, though readily soluble in acids. On dissolving it in hydrochloric acid, for instance, we obtain a solution of perchloride of iron, a crystalline body

which diffuses with the greatest facility. But when hydrated peroxide of iron is digested in this solution, it becomes gradually dissolved, and we have formed a basic colloidal chloride, its basicity being probably dependent on its colloidal nature, which we know produces a high atomicity. Now, when this liquid is dialyzed, the hydrochloric acid passes away, and a pure aqueous solution of peroxide of iron is left on the dialyzer. And mark this curious action. When we have the oxide of iron dissolved in an equivalent quantity of hydrochloric acid, the crystalloid chloride of iron is formed, which dialyzes without decomposition, the oxide not separating from the acid. But when we introduce a larger quantity of oxide of iron, we form a colloid compound, and the hydrochloric acid can then dialyze completely away from the oxide, which will remain in aqueous solution. With a small quantity of oxide, the acid and base go through together; with a larger quantity of oxide, the acid passes away, and the colloid base is left behind. Here I have a colloidal solution of peroxide of iron, which was prepared in the manner I have just described to you, and which I will now proceed to pectize by the addition of a little common salt. If I were simply to pour some of this colloidal liquid into a glass, and then add the reagent to it, there would be no effect recognizable at a distance; but I shall, I hope, be able to render the result visible to all of you by means of the electric lamp which Dr. Tyndall has kindly arranged for me. We have the solution of colloidal oxide of iron in this glass tray; and I wish first to show you its color and transparency. [A beam of light was thrown through the solution on to a screen.] You see that the liquid has an orange-brown color, and is perfectly transparent. I will now add a little common salt, and you perceive that it instantly produces a perfect pectizing or gelatinizing of the mass.

While we have the electric lamp in order, I will direct your attention to another colloidal substance. I have here some Prussian blue, a compound that is usually quite insoluble in water. It is, however, capable of being dissolved very readily in oxalic acid, and when the oxalic acid solution is allowed to dialyze, the oxalic acid passes through, and the Prussian blue is left in the form of an aqueous colloidal solution, capable of being gelatinized like the silica and oxide of iron solutions. In this tray we have our solution of colloidal Prussian blue. [A beam of light was then thrown through it on a screen.] You perceive it is of a blue color and perfectly transparent, ready, however, to pectize on the addition of a small quantity of some foreign substance. We will take, in this instance, a drop of dilute sulphuric acid. We are operating with a somewhat weak solution, in order to allow the light to pass through, and the pectization of a weak solution is not instantaneous. But in the course of a minute or so it will, I have no doubt, be visible. Even now it is beginning. The pectization is gradually taking place, and you can now see clearly that the liquid is no longer homogeneous, but that the precipitated colloid or gelatinous prussiate of iron exists in suspension throughout. The appearance will become more characteristic in a moment or two. [Here the changes became clearly perceptible to the audience.]

In the one moment that remains to me I will show you another experiment of a similar description, made with a very beautiful substance, not the blue prussiate of iron, but the red prussiate of copper, which is, under ordinary circumstances, an insoluble compound. It is readily thrown down by adding a little prussiate of potash to a salt of copper, as you perceive. On dilution, the color and character of the precipitate are rendered very apparent. Here we have the prussiate of copper thrown down of a chocolate red color. If we pour the whole on to a filter, a colorless liquid passes through, as you see, while the chocolate body being insoluble remains on the filter. But this body, though ordinarily insoluble in pure water, is soluble in a solution of oxalate of ammonia, and when this mixed liquid is submitted to dialysis, the oxalate of ammonia passes through the membrane, while this curious liquid, an aqueous solution of red prussiate of copper, remains on the dialyzer. This solution has some of the characters of Mr. Faraday's gold liquids: although the great mass of the prussiate is in a state of real solution, a minute portion seems to be only in the state of suspension, and hence a curious red opacity is manifested when the liquid is examined by reflected light. I shall be able to show you the color and transparency of the solution by means of the electric lamp. [A beam of light was here thrown through the liquid.] At present you perceive the solution is perfectly transparent, homogeneous, and of a splendid red color. But this body is pectized with very great ease, and on adding a drop of dilute sulphuric acid, you see an immediate formation of large flocks of gelatinous substance, which now completely obstruct the passage of light; whereas the clear solution, as you saw, allowed light to pass through it with the greatest readiness.

Now, this discovery by Mr. Graham of dialysis, of the capability which some bodies have, and others have not, to pass through membranes, and of the broad distinctions between the two classes of bodies, bids fair to open out an entirely new field of inquiry. The constant intervention of colloid septa in so many of the phenomena of animal and vegetable life, gives to the subject of dialysis a high physiological interest, and it will, doubtless, exercise an important influence in the progress of physiological research. It will also serve to explain many of the phenomena of inorganic Nature, more especially in relation to bodies which are now crystalline, but were once colloidal. It will also be of the greatest service in its applications to toxicology, pharmacy, and practical chemistry, by enabling us to effect a most perfect separation of different substances which could not be separated by any other means. It is not for me to express the obligation which science is under to Mr. Graham for investigating this important subject so laboriously and successfully; but I cannot conclude without expressing publicly my personal thanks to him for the opportunity he has given me, and the pleasure he has afforded me, of bringing this subject under your notice, and for his kindness in providing me with these very beautiful illustrations of dialytic phenomena.

The Properties of Iron, and its Resistance to Projectiles at High Velocities. By Wm. Fairbairn, F.R.S. Read before the Royal Institute.

From the Lond. Civ. Eng. and Arch. Journal, August, 1862.

We have no correct record as to the exact time when wrought iron plates were first employed for the purpose of building vessels. It is, however, certain that iron barges were in use on canals at the close of the last century. In 1824, Mr. Manley, of Staffordshire, built an iron steamboat for the navigation of the river Seine, and this was the first iron vessel that attempted a sea voyage. She was navigated from this country to Havre, by the late Admiral Sir Charles Napier, and although constructed for shallow rivers, she nevertheless crossed the channel in perfect safety. From that time to 1830, no attempt was made to build iron vessels, and nothing was done towards ascertaining the properties of iron as a material for ship-building.

A series of experiments, instituted by the Forth and Clyde Canal Company in 1829–30, to ascertain the law of traction of light boats at high velocities on canals, led to the application of iron for the construction of vessels; and the lightness of these new vessels, combined with their increased strength, suggested the extended application of the material in the construction of vessels of much larger dimensions, and ultimately to those of the larger class, both in the war and mercantile navy. Considerable difficulty, however, existed with regard to the navy; and although the principle of iron construction as applied to merchant vessels and packets was fully established, it was nevertheless considered inapplicable, until of late years, for ships of war. It is true, that until the new system of casing the sides of vessels first introduced by the Emperor of the French, in 1854, was established, the iron ship was even more dangerous under fire than one built entirely of wood. Now, however, that thick iron plates are found sufficiently strong, under ordinary circumstances, to resist the action of guns not exceeding 120-pounders, for a considerable length of time, the state of the navy and the minds of our naval officers have entirely changed. We must, therefore, now look to new conditions, new materials, and an entirely new construction, if we are to retain our superiority as mistress of the seas. There yet remain amongst us those who contend for the wooden walls, but they are no longer applicable to the wants of the state; and I am clearly of opinion that we cannot afford to trifle with so important a branch of the public service as to fall behind any nation, however powerful and efficient they may be in naval construction. Having satisfied ourselves that this desideratum must be attained, at whatever cost, I shall now endeavor to point out such facts as in my opinion relate to the changes that are now before us, and simply endeavor to show—

1st. The description of iron best calculated to secure strength and durability in the construction of ships of war.

2d. The distribution and best forms of construction to attain this object; and,

Lastly. The properties of iron best calculated to resist the penetration of shot at high velocities.

Properties of Iron.—If we are desirous to attain perfection in mechanical, architectural, or ship-building construction, it is essential that the engineer or architect should make himself thoroughly acquainted with the properties of the materials which he employs. It is unimportant whether the construction be a house, a ship, or a bridge. We must possess correct ideas of the strength, proportion, and combination of the parts, before we can arrive at satisfactory results; and to effect these objects the naval architect should be conversant with the following facts relating to the resisting powers of malleable and rolled iron to a tensile strain. The resistance in tons per square inch of—

Yorkshire iron is	24·50 tons.
Derbyshire "	20·25 "
Shropshire "	22·50 "
Staffordshire "	20·00 "

Strength of Riveted Joints.—The architect having fortified himself with the above facts, will be better able to carry out a judicious distribution of the frames, ribs, and plates of an iron ship, so as to meet the various strains to which it may be subjected, and ultimately to arrive at a distribution where the whole in combination presents uniformity of resistance to repeated strains, and the various changes it has to encounter in actual service.

There is, however, another circumstance, of deep importance to the naval architect, which should on no account be lost sight of, and that is, the comparative values of the riveted joints of plates to the plates themselves. These, according to experiments, give the following results:—

Taking the cohesive strength of the plate at	100
The strength of the double-riveted joint was found to be	70
And the single-rivited joint	56

These proportions apply with great force to vessels requiring close riveting, such as ships and boilers that must be water-tight, and in calculation it is necessary to make allowances in that ratio.

Strength of Ships.—Of late years it has been found convenient to increase the length of steamers and sailing vessels to as much as eight or nine times their breadth of beam, and this for two reasons; first, to obtain an increase of speed by giving fine sharp lines to the bow and stern; and second, to secure an increase of capacity for the same midship section, by which the carrying powers of the ship are greatly augmented. Now, there is no serious objection to this increase of length, which may or may not have reached the maximum. But, unfortunately, it has hitherto been accomplished at a great sacrifice to the strength of the ship. Vessels floating on water and subjected to the swell of a rolling sea—to say nothing of their being stranded or beaten upon the rocks or sand banks of a lee shore—are governed by the same laws of transverse strain as simple hollow beams, like the tubes of the Conway and Britannia tubular bridges. Assuming this to be true—and indeed it scarcely requires demonstration—it follows that we cannot lengthen a ship with impunity without adding to her

depth, or to the sectional area of the plates in the middle along the line of the upper deck.

If we take a vessel of the ordinary construction, or what some years ago was considered the best—300 feet long, 41 feet 6 inches beam, and 26 feet 6 inches deep—we shall be able to show how inadequately she is designed to resist the strains to which she would be subjected. To arrive at these facts we shall approximate nearly to the truth by treating it as a simple beam; and this is actually the case, to some extent, when a vessel is supported at each end by two waves, or when rising on the crest of another, supported at the centre with a stem and stern partially suspended. Now in these positions the ship undergoes, alternately, a strain of compression and of tension along the whole section of the deck, corresponding with equal strains of tension and compression along the section of the keel, the strains being reversed according as the vessel is supported at the ends or the centre. These are, in fact, the alternate strains to which every long vessel is exposed, particularly in seas where the distance between the crests of the waves does not exceed the length of the ship.

It is true that a vessel may continue for a number of voyages to resist the continuous strains to which she is subjected whilst resting on the water; but supposing in stress of weather, or from some other cause, she is driven on rocks, with her bow and stern suspended, the probability is that she would break in two, separating from the insufficiency of the deck on the one hand, and the weakness of the hull on the other. This is the great source of weakness in wrought iron vessels of this construction, as well as of wooden ones, when placed in similar trying circumstances.*

Changes in Progress.—Having directed attention to the strength of ships, and the necessity for their improved construction, we may now advert to the changes by which we are surrounded, and to the revolution now pending over the destinies of the navy, and the deadly weapons now forging for its destruction. It is not for us alone, but for all other maritime nations, that these Cyclopean monsters are now issuing from the furnaces of Vulcan; and it behooves all those exposed to such merciless enemies to be upon their guard, and to have their *Warriors*, *Merrimacs*, and *Monitors* ever ready, clothed in mail from stem to stern, to encounter such formidable foes. It has been seen, and every experiment exemplifies the same fact, that the iron ship with its coat of armor is a totally different construction to that of the wooden walls which for centuries have been the pride and glory of the country. Three-deckers, like the *Victory* and the *Ville de Paris* of the last century, would not exist an hour against the sea-monsters now coming into use.

The days of our wooden walls are therefore gone; and instead of the gallant bearing of a 100-gun ship, with every inch of canvas set, dashing the spray from her bows, and careering merrily over the ocean, we shall find in its place a black demon, some five or six hundred feet long, stealing along, with a black funnel and flag-staff, on her mission

* See Vol. I. of the Transactions of the Institution of Naval Architects, on the Strength of Iron Ships.

of destruction, and scarcely seen above water excepting to show a row of teeth on each side as formidable as the iron carcass that is floating below. This may, with our present impressions, be considered a perspective of the future navy of England—probably not encouraging—but one on which the security of the country may ultimately have to depend, and to the construction of which the whole power and skill of the nation should be directed. I have noticed these changes, which are fast approaching, from the conviction that the progress of the applied sciences is not only revolutionizing our habits in the development of naval construction, as in every other branch of industry, but the art of war is undergoing the same changes as those which have done so much for the industrial resources of the country in times of peace. It is therefore necessary to prepare for the changes now in progress, and endeavor to effect them on principles calculated not only to insure security, but to place this country at the head of constructive art. It is to attain these objects that a long and laborious class of experiments have been undertaken by the Government, to determine how the future navy of England shall be built, how it should be armed, and under what conditions it can best maintain the supremacy of the seas. This question does not exclusively confine itself to armor-plated vessels, but also to the construction of ships, which in every case should be strong and powerful enough to contend against either winds or waves, or to battle with the enemy. It is for these reasons that I have ventured to direct attention to the strength of vessels, and to show that some of our mercantile ships are exceedingly weak, arising probably from causes of a mistaken economy on the one hand, or a deficiency of knowledge or neglect of first principles on the other.

Now, it is evident that our future ships of war of the first class must be long and shallow; moreover, they must contain elements of strength and powers of resistance that do not enter into the construction of vessels that are shorter and nearly double the depth. If we take a first-rate ship of the present construction, such as the *Duke of Wellington*, and compare it with one of the new or forthcoming construction, carrying the same weight of ordnance, we should require a vessel nearly twice the length and little more than half her depth. Let us for example suppose the *Duke of Wellington* to be 360 feet long and 60 feet deep, and the new construction 500 ft. long and 46 ft. deep; we should then have for the resistance of the *Duke of Wellington* to a transverse strain tending to break her back, $w = \frac{a\,d\,c}{l}$. Taking 60 as the constant, and the area of the bottom and upper deck as 1060 sq. inches, we have $w = \frac{1060 \times 60 + 60}{340} = 12{,}223$ tons as the weight that would break her in the middle. Let us now take the new ship, and give her the same area top and bottom, and again we have

$$w = \frac{1060 + 46 \times 60}{500} = 5851 \text{ tons},$$

which is less than half the strength. From this it is obvious—if we

are correct in our calculations—that the utmost care and attention are requisite in design and construction to insure stability and perfect security in the build of ships.

Mechanical Properties of Iron.—It is unnecessary to give more examples in regard to strength, and the proportions that should be observed in the construction of our future navy. I have simply directed attention to it as a subject of great importance, and one that I am satisfied will receive careful consideration on the part of the Admiralty and the Comptroller of the Navy.

The next question for consideration is the properties of iron best calculated to resist the penetration of shot at high velocities, and in this I am fortunate in having before me the experiments of the Committee on Iron Plates, which may be enumerated as under:—

Specific gravity,	7·7621
Tensile strength in tons per square inch,	24·802
Compression per unit of length in tons,	14·203
Statical resistance to punching in tons, 1-inch plate,	40·1804

Remarks.—The specimens subjected to compression were gradually squeezed down to one-half their original height, increasing at the same time in diameter till they attained 90 tons on the square inch.

In these experiments, four descriptions of iron were selected, marked A, B, C, D; the two first and last were taken from rolled and hammered iron plates, excepting C, which was homogeneous, and gave higher results to tension and dead pressure than the others. In density and tenacity they stood as follows:—

Mark on Plates.	Density.	Tenacity in Tons.
A Plates,	7·8083	24·644
B Plates,	7·7035	23·354
C Plates, homogeneous,	7·9042	27·032
D Plates,	7·6322	24·171

Here it will be observed, that the strengths are in the ratio of the densities, excepting only the B plates, which deviate from that law.

On the resistance to compression, it will be seen that in none of the experiments was the specimen actually crushed; but they evidently gave way at a pressure of 13 tons per square inch, and were considerably cracked and reduced in height by increased pressure.

From the experiments on punching, we derive the resistance of B, C, D plates to a flat-ended instrument forced through the plate by dead pressure as follows:—

Mark on Plates.	Shearing Strain in Tons per square inch.	Ratio, taking A as unity.
A Plates,	19·511	1·000
B Plates,	17·719	0·907
C Plates,	27·704	1·168
D Plates,	17·035	0·873

Here it may be noticed that the difference between the steel plates of series C, and the iron plates of series A, is not considerable, though in all others the steel plates exhibit a superiority in statical resistance.

(To be Continued.)

Hardening Iron and Steel.

From the London Builder, No. 1015.

Mr. E. Partridge, of the Patent Axle Works, Smethwick, has provisionally specified an invention which consists in first heating the article to be hardened in a bath of lead or other suitable molten metals, or in a retort, so as to be protected from the direct action of fire. In applying to it, either in the bath or retort, or immediately on its withdrawal therefrom, a composition presently to be described, either in powder or liquid, in some cases the article is returned to the bath or retort after such application. In preparing the composition, he takes prussiate of potash or other substance containing cyanogen, or possessing like chemical properties, and reduces it to powder. He mixes with it powdered nitre and common salt, and sets fire to the composition. He takes the resulting ashes or substance remaining after the firing, and powders it. The powder liquefies under heat, and he uses it alone or mixed with charcoal (animal or vegetable), or other suitable form of carbon; or he liquefies the powder by dissolving it in liquid ammonia or other suitable solvent, and applies it to the articles to be hardened in a liquid state.

Lecture on Force. By Prof. TYNDALL, at the Royal Institution.

From the London Mechanics' Magazine, July, 1862.

The existence of the International Exhibition suggested to our honorary Secretary the idea of devoting the Friday evenings after Easter of the present year to discourses on the various agencies on which the material strength of England is based. He wished to make iron, coal, cotton, and kindred matters, the subject of these discourses; opening the series by a discourse on the Great Exhibition itself; and he wished me to finish the series by a discourse on "Force" in general. For some months I thought over the subject at intervals, and had devised a plan of dealing with it; but three weeks ago I was induced to swerve from this plan, for reasons which shall be made known towards the conclusion of the discourse.

We all have ideas more or less distinct regarding force; we know in a general way what muscular force means, and each of us would less willingly accept a blow from a pugilist than have his ears boxed by a lady. But these general ideas are not now sufficient for us; we must learn how to express numerically the exact mechanical value of the two blows; this is the first point to be cleared up.

A sphere of lead weighing 1 lb. was suspended at a height of 16 ft. above the theatre floor. It was liberated, and fell by gravity. That

weight required exactly a second to fall to the earth from that elevation; and the instant before it touched the earth, it had a velocity of 32 feet a second. That is to say, if at that instant the earth were annihilated, and its attraction annulled, the weight would proceed through space at the uniform velocity of 32 feet a second.

Suppose that instead of being pulled downward by gravity, the weight is cast upward in opposition to the force of gravity, with what velocity must it start from the earth's surface in order to reach a height of 16 feet? With a velocity of 32 feet a second. This velocity imparted to the weight by the human arm, or by any other mechanical means, would carry the weight up to the precise height from which it had fallen.

Now the lifting of the weight may be regarded as so much mechanical work. I might place a ladder against a wall, and carry the weight up a height of 16 feet; or I might draw it up to this height by means of a string and pulley, or I might suddenly jerk it up to a height of 16 feet. The amount of work done in all these cases, as far as the raising of the weight is concerned, would be absolutely the same. The absolute amount of work done depends solely upon two things: first of all, on the quantity of matter that is lifted; and secondly, on the height to which it is lifted. If you call the quantity or mass of matter m, and the height through which it is lifted h, then the product of m into h or mh, expresses the amount of work done.

Supposing, now, that instead of imparting a velocity of 32 feet a second to the weight, we impart twice this speed, or 64 feet a second. To what height will the weight rise? You might be disposed to answer, "To twice the height:" but this would be quite incorrect. Both theory and experiment inform us that the weight would rise to four times the height: instead of twice 16, or 32 feet, it would reach four times 16, or 64 feet. So also, if we treble the starting velocity, the weight would reach nine times the height; if we quadruple the speed at starting, we attain sixteen times the height. Thus, with a velocity of 128 feet a second at starting, the weight would attain an elevation of 256 feet. Supposing we augment the velocity of starting seven times, we should raise the weight to 49 times the height, or to an elevation of 784 feet.

Now the work done—or, as it is sometimes called, the mechanical effect—as before explained, is proportional to the height, and as a double velocity gives four times the height, a treble velocity nine times the height, and so on, it is perfectly plain that the mechanical effect increases as the square of the velocity. If the mass of the body be represented by the letter m, and its velocity by v, then the mechanical effect would be represented by $m\,v^2$. In the case considered, I have supposed the weight to be cast upward, being opposed in its upward flight by the resistance of gravity; but the same holds true if I send the projectile into water, mud, earth, timber, or other resisting material. If, for example, you double the velocity of a cannon-ball, you quadruple its mechanical effect. Hence the importance of augmenting the velocity of a projectile, and hence the philosophy of Sir

William Armstrong in using a 50 lb. charge of powder in his recent striking experiments.

The measure then of mechanical effect is the mass of the body multiplied by the square of its velocity.

Now in firing a ball against a target, the projectile, after collision, is often found hissing hot. Mr. Fairbairn informs me that in the experiments at Shoeburyness it is a common thing to see a flash of light, even in broad day, when the ball strikes the target. And if I examine my lead weight after it has fallen from a height, I also find it heated. Now here experiment and reasoning lead us to the remarkable law that the amount of heat generated, like the mechanical effect, is proportional to the product of the mass into the square of the velocity. Double your mass, other things being equal, and you double your amount of heat; double your velocity, other things remaining equal, and you quadruple your amount of heat. Here then we have common mechanical motion destroyed and heat produced. I take this violin bow and draw it across this string. You hear the sound. That sound is due to motion imparted to the air, and to produce that motion a certain portion of the muscular force of my arm must be expended. We may here correctly say, that the mechanical force of my arm is converted into music. And in a similar way we say that the impeded motion of our descending weight, or the arrested cannon-ball, is converted into heat. The mode of motion changes, but it still continues motion; the motion of the mass is converted into a motion of the atoms of the mass; and these small motions communicated to the nerves, produce the sensation which we call heat. We, moreover, know the amount of heat which a given amount of mechanical force can develop. Our lead ball, for example, in falling to the earth generated a quantity of heat sufficient to raise the temperature of its own mass three-fifths of a Fahrenheit degree. It reached the earth with a velocity of 32 feet a second, and 40 times this velocity would be a small one for a rifle bullet; multiplying three-fifths by the square of 40, we find that the amount of heat developed by collision with the target would, if wholly concentrated in the lead, raise its temperature 960°. This would be more than sufficient to fuse the lead. In reality, however, the heat developed is divided between the lead and the body against which it strikes: nevertheless, it would be worth while to pay attention to this point, and to ascertain whether rifle bullets do not, under some circumstances, show signs of fusion.

From the motion of sensible masses, by gravity and other means, the speaker passed to the motion of atoms towards each other by chemical affinity. A collodion balloon filled with a mixture of chlorine and hydrogen was hung in the focus of a parabolic mirror, and in the focus of a second mirror, 20 feet distant, a strong electric light was suddenly generated; the instant the light fell upon the balloon, the atoms within it fell together with explosion, and hydrochloric acid was the result. The burning of charcoal in oxygen was an old experiment, but it had now a significance beyond what it used to have; we now regard the act of combination on the part of the atoms of oxygen and

coal exactly as we regard the clashing of a falling weight against the earth. And the heat produced in both cases is referable to a common cause. This glowing diamond, which burns in oxygen as a star of white light, glows and burns in consequence of the falling of the atoms of oxygen against it. And could we measure the velocity of the atoms when they clash, and could we find their number and weight, multiplying the mass of each atom by the square of its velocity, and, adding all together, we should get a number representing the exact amount of heat developed by the union of the oxygen and carbon.

Thus far we have regarded the heat developed by the clashing of sensible masses and of atoms. Work is expended in giving motion to these atoms or masses, and heat is developed. But we reverse this process daily, and by the expenditure of heat execute work. We can raise a weight by heat; and in this agent we possess an enormous store of mechanical power. This pound of coal which I hold in my hand, produces by its combination with oxygen an amount of heat which, if mechanically applied, would suffice to raise a weight of 100 lbs. to a height of 20 miles above the earth's surface. Conversely, 100 lbs. falling from a height of 20 miles, and striking against the earth, would generate an amount of heat equal to that developed by the combustion of a pound of coal. Wherever work is done by heat, heat disappears. A gun which fires a ball is less heated than one which fires blank cartridge. The quantity of heat communicated to the boiler of a working steam engine is greater than that which could be obtained from the re-condensation of the steam after it had done its work; and the amount of work performed is the exact equivalent of the amount of heat lost. Mr. Smyth informed us in his interesting discourse that we dig annually 84,000,000 of tons of coal from our pits. The amount of mechanical force represented by this quantity of coal seems perfectly fabulous. The combustion of a single pound of coal, supposing it to take place in a minute, would be equivalent to the work of 300 horses; and if we suppose 108,000,000 of horses working day and night with unimpaired strength, for a year, their united energies would enable them to perform an amount of work just equivalent to that which the annual produce of our coal-fields would be able to accomplish.

Comparing the energy of the force with which oxygen and carbon unite together, with ordinary gravity, the chemical affinity seems almost infinite. But let us give gravity fair play; let us permit it to act throughout its entire range. Place a body at such a distance from the earth that the attraction of the earth is barely sensible, and let it fall to the earth from this distance. It would reach the earth with a final velocity of 36,747 feet in a second; and on collision with the earth, the body would generate about twice the amount of heat generated by the combustion of an equal weight of coal. We have stated that by falling through a space of 16 feet our lead bullet would be heated three-fifths of a degree; but a body falling from an infinite distance has already used up 1,299,999 parts out of 1,300,000 of the earth's pulling power,

whence it has arrived within 16 feet of the surface; on this space only $\frac{1}{13000}$ths of the whole force is exerted.

Let us now turn our thoughts for a moment from the earth towards the sun. The researches of Sir John Herschel and M. Pouillet have informed us of the annual expenditure of the sun as regards heat; and by an easy calculation we ascertain the precise amount of the expenditure which falls to the share of our planet. Out of 2,300,000,000 parts of light and heat, the earth receives one. The whole heat emitted by the sun in a minute would be competent to boil 12,000,000,000 of cubic miles of ice-cold water. How is this enormous loss made good? Whence is the sun's heat derived, and by what means is it maintained? No combustion, no chemical affinity with which we are acquainted, would be competent to produce the temperature of the sun's surface. Besides, were the sun a burning body merely, its light and heat would assuredly speedily come to an end. Supposing it to be a solid globe of coal, its combustion would only cover 4600 years of expenditure. In this short time it would burn itself out. What agency then can produce the temperature and maintain the outlay? We have already regarded the case of a body falling from a great distance towards the earth, and found that the heat generated by its collision would be twice that produced by the combustion of an equal weight of coal. How much greater must be the heat developed by a body falling towards the sun! The maximum velocity with which a body can strike the earth is about 7 miles in a second; the maximum velocity with which it can strike the sun is 390 miles in a second. And as the heat developed by the collision is proportional to the square of the velocity destroyed, an asteroid falling into the sun with the above velocity would generate about 10,000 times the quantity of heat generated by the combustion of an asteroid of coal of the same weight. Have we any reason to believe that such bodies exist in space, and that they may be raining down upon the sun? The meteorites flashing through the air are small planetary bodies, drawn by the earth's attraction, and entering our atmosphere with planetary velocity. By friction against the air they are raised to incandescence and caused to emit light and heat. At certain seasons of the year they shower down upon us in great numbers. In Boston 240,000 of them were observed in nine hours. There is no reason to suppose that the planetary system is limited to "vast masses of enormous weight;" there is every reason to believe that space is stocked with smaller masses, which obey the same laws as the larger ones. That lenticular envelope which surrounds the sun, and which is known as the Zodiacal light, is probably a crowd of meteors; and moving as they do in a resisting medium, they must continually approach the sun. Falling into it, they would be competent to produce the heat observed, and this would constitute a source from which the annual loss of heat would be made good. The sun, according to this hypothesis, would be continually growing larger; but how much larger? Were our moon to fall into the sun, it would develop an amount of heat sufficient to cover one or two years loss; and were our earth to fall into the sun, a century's loss would be made

good. Still, our moon and our earth, if distributed over the surface of the sun, would utterly vanish from perception. Indeed, the quantity of matter competent to produce the necessary effect would, during the range of history, produce no appreciable augmentation in the sun's magnitude. The augmentation of the sun's attractive force would be more appreciable. However this hypothesis may fare as a representant of what is going on in nature, it certainly shows how a sun might be formed and maintained by the application of known thermo-dynamic principles.

Our earth moves in its orbit with a velocity of 68,040 miles an hour. Were this motion stopped, an amount of heat would be developed sufficient to raise the temperature of a globe of lead of the same size as the earth 384,000 degrees of the Centigrade thermometer. It has been prophesied that "the elements shall melt with fervent heat." The earth's own motion embraces the conditions of fulfilment; stop that motion, and the greater part, if not the whole, of her mass would be reduced to vapor. If the earth fell into the sun, the amount of heat developed by the shock would be equal to that developed by the combustion of 6435 earths of solid coal.

(To be Continued.)

Steam Boiler Explosions.

From the Journal of the Society of Arts, No. 502.

At the last ordinary monthly meeting of the Executive Committee of the Association for the Prevention of Steam Boiler Explosions on Tuesday, June 24, Hugh Mason, Esq., Vice-President, in the chair, Mr. L. E. Fletcher, chief engineer, presented his monthly report, of which the following is an abstract:—

"During the last month there have been examined 224 engines—5 specially; 400 boilers—9 specially, 8 internally, 68 thoroughly, and 315 externally; in addition to which 7 of these boilers have been tested by hydraulic pressure. The following defects have been found in the boilers examined:—Fracture, 5 (2 dangerous); corrosion, 43 (7 dangerous); safety-valves out of order, 7; water gauges, ditto, 11; pressure gauges, ditto, 6; blow-off cocks, ditto, 36; fusible plugs, ditto, 3; furnaces out of shape, 6 (1 dangerous); over pressure, 4; blistered plates, 4; total, 125 (10 dangerous). Boilers without glass water-gauges, 8; without pressure gauges, 5; without blow-off cocks, 7; without back pressure valves, 26.

"No explosion has happened during the past month to any boiler under the inspection of this Association, neither have I heard of the occurrence of any in other parts of the country.

"Advantage has been taken of the very general stoppage of the works during Whit-week to make as many 'internal and thorough' boiler examinations as possible, the ordinary routine of visits being entirely laid aside in order that the inspectors might exclusively devote themselves to this special branch. Applications for these exa-

minations have this year been so numerous that the inspectors were incessantly occupied upon them during the whole week, notwithstanding which, however, a few late applications could not be complied with. Members might avail themselves of any holidays peculiar to their own district, for securing these 'internal and thorough' examinations. Early applications should in all cases be made for the visit of inspection.

"Several cases of extensive corrosion were revealed by these examinations, and which attested to what a dangerous extent they are too frequently postponed. In one instance, the plates at the bottom of a boiler were so reduced in thickness, that the engine attendant feared lest the removal of the cake of incrustation should rob them of so much assistance as to prove fatal to the integrity of the shell.

"I find it necessary again to repeat that it is absolutely imperative, if these examinations are to be satisfactory, that the flues should be thoroughly swept, and the boilers suitably prepared, otherwise the condition of the plates cannot be ascertained; while, on the score of economy, I would remark, in passing, that our members can scarcely be aware of the amount of fuel wasted by allowing the plates of their boilers, while in work, to be coated with so non-conducting a substance as soot. Feed water passed through heaters loses 30 degrees of its temperature within a week after sweeping, while the utility of the heater is almost lost if allowed to go unswept for a longer period. This will give some idea of the loss occasioned to boilers by neglect, and I have found the soot to hang from the surface of the plates in complete festoons immediately after the flues themselves had been passed as swept.

Safe Working Pressure of Boilers, and Hooping of Flues.—"For some time since I have been desirous of touching upon the point of Safe Working Pressures for boilers, since it not unfrequently happens that it is necessary to warn our members on account of excess.

"The scale adopted by the Association as a general standard is as follows:—For shells of boilers 7 feet in diameter, made of $\frac{3}{8}$th plate, the safe working pressure 50 pounds; if of $\frac{7}{16}$th plate, 60 pounds; and other dimensions in proportion. This allowance corresponds with the general practice of the manufacturing engineers of the district, is quite as high as the standard in other parts of the country, and considerably in excess of that permitted either in France, Holland, or Belgium, by their respective governments. It must, however, be distinctly understood, that this standard should not be applied arbitrarily in every case, without any allowance being made for the attendant circumstances. It is only applicable in cases where the boiler is well made, both as regards materials and workmanship, and where the condition of the plates is good. It would be highly dangerous to apply it to boilers weakened by the wear and tear of years; while on the other hand, a new and thoroughly well made boiler might for a time be allowed to work at a pressure slightly in excess of that given. But this could only be safe where every thing is in first rate condition.

"It is a very common idea that the bursting pressure of a boiler is six times as high as that given above as its safe working pressure. This, however, I am persuaded, is a great mistake, and leads in many cases to undue confidence. I am confirmed in this conclusion by the constant examination of the rent plates in boilers that have exploded, where I find that, even where explosion results from thinning of the plates, rupture ensues long before they are reduced to one-sixth of their original thickness, and in one case I knew a well made and nearly new boiler, in first rate condition, to explode, on account of only a comparatively slight increase of pressure, which had accidentally been allowed through an error in the steam gauge. In this case, that at which the boiler actually burst did not exceed its ordinary working pressure by more than 50 per cent., the one being about 90 pounds, the other 60 pounds. I believe that an application of any thing like six times the pressure given in the scale above, would burst most of the boilers in Lancashire, and where it has been actually attempted by hydraulic pressure, the steam domes have been found to tear off long before the strain referred to has been attained. I cannot, therefore, think that shells of cylindrical boilers can be worked without risk at a higher pressure than that given in the preceding scale, unless under very exceptional circumstances.

"With regard to the Furnace Tubes which are exposed to external pressure, I am glad to find that the practice is becoming increasingly general of strengthening them either with flanched seams or hoops, the hoops being made either of angle iron, T-iron, or other approved form; and since it too frequently happens that flues are not made in the first instance truly cylindrical, on which their strength so much depends, and that other sources of weakness creep into the manufacture unawares, it is extremely desirable that no new boiler should be constructed with flues unstrengthened in the way just described, however slight the working pressure may be.

"These hoops are frequently added to boilers after their first construction, and since some of our members have suffered inconvenience from the imperfect manner in which they have been fixed, I may state the method found by experience to be the best, which is as follows:—The hoops, if made in two halves, may be passed in through the manhole, and then be secured to the furnace tubes when in position. They should not, however, be brought in direct contact with the plates of the tube, but should have ferrules of about an inch thick placed between the two, so as to leave a clear space all round through which the water can circulate. Where this space has been omitted, the plates have been found in some places to crack at the rivet holes, and in others to blister and buckle, in consequence of which many plates have had to be cut out and the hoops removed, from which the system of hooping has been in some cases unfairly condemned. Where, however, the ferrules have been introduced and the water space allowed, no injury has been found to arise to the plates even over the hottest part of the fire. The rivets uniting the hoops to the furnace tube should pass through these ferrules, and be spaced about six inches apart,

while the two halves of the hoops should be connected together by butt strips riveted to their ends at their back. When hoops are applied as an after-clap in this way, angle iron is preferable to T-iron, as the flanch, being narrower, is less liable to cause overheating of the plate. It may be necessary to vary the size of the angle iron in some cases, but, generally speaking, one three inches in the flanch and half an inch in thickness will be found to answer every purpose. It is sometimes the practice to put two angle irons back to back. This is quite unnecessary, and a single one is all that is required. A drawing, to show the arrangement recommended, has been made for the assistance of the members, and can be seen on application at the offices of the Association.

"Since writing the above, I have met with some additional cases, where considerable expense has been incurred by having to remove angle iron hoops from furnace tubes, in consequence of the injudicious mode in which they have been fixed, and would therefore impress upon our members the importance of attention to the above, if they wish to prevent the recurrence of disappointment in their own case."

On the Best Form and Dimensions of a Seat.

From the London Builder, No. 1014.

A correspondent writes as follows:—

When a workman is about to make a saddle, he does not begin with a T-square and straight-edge, and make every part of it with right angles; but proceeds to model a saddle-tree, with the underside fitted to the horse's back, and the upper surface formed so as to extend as much as possible the part on which the rider sits. The same principle applies to a seat. The form of the human frame should be considered, and the seat so modelled as to extend the resting-surface, and be adapted to the average size of man. Keeping this in view, the best dimensions for a comfortable church pew would appear to be—

Width of pew from centre to centre,	2 ft.	9 ins.
Height of back, total,	3	2

Divided thus:—

From floor to upper surface of seat at back,	1 ft.	4 ins.
From thence, perpendicular,	0	5
From thence, sloping about 1 inch in 4 inches,	1	5
	3 ft.	2 ins.

Seat, total breadth, 15 inches, divided thus:—

From back, forwards, decline ½ inch in	0 ft.	4 ins.
From thence, rise 1½ inch in	0	9½
From thence, to the front, level,	0	1½
	1 ft.	3 ins.

Making the height of the seat at the front 17 inches.

There is abundant room for men's hats under the seat.

If the seats are to have cushions, they should be half an inch lower,

and that half inch added to the perpendicular part of the back, making it 5½ inches.

This perpendicular part of the back is of essential importance to the comfort of the seat, as it gives support to the bony frame of the loins, while the slope above it leaves room for the motion of the heart and lungs, and affords rest to the shoulders.

The form of the seat also gives support to the limbs where they grow thinner, and in every way extends the surface on which the body rests.

This general form and these dimensions have been worked out, after much comparison and study, by Mr. William Brown, of Glasgow. The general principles, says the writer, may be also employed in the improved construction of benches, couches, and chairs.

On the Uses of Carbolic Acid for Engineers.

From the Lond. Mechanics' Magazine, July, 1862.

SIR:—Most persons have by this time heard that there is such a substance as carbolic acid; comparatively few have seen it, fewer still have used it, and no one (so far as I can find) has yet noticed a very remarkable property which it possesses in relation to practical mechanics. For the information of those to whom the substance itself is unknown, a word or two will be sufficient to introduce it to their notice. Carbolic acid is one of the products of the destructive distillation of coal, and till within a few years vast quantities of it were utterly wasted. When perfectly pure, it is a white crystalline solid, which by absorbing water soon changes into a colorless refractive liquid, having a faint odor of roses and tar. It is not an acid in the popular sense, not being either sour or corrosive, and should therefore, perhaps, be generally designated by its other title of phenole. Crude carbolic acid may be obtained in bulk for about a shilling a gallon, and is a dark, tarry liquid, containing, perhaps, from ten to twenty different substances, in a state of mechanical admixture. Fortunately, this crude acid is available for the purposes to which I invite the attention of your readers. Just as oil is an *anti-frictional* liquid, so is phenole *pro-frictional;* or, to state it more correctly, as oil appears to keep surfaces in motion asunder by interposing a thin film between them, so phenole appears to make them *bite* and bind, by bringing them into absolute contact (after a manner of speaking), and removing even the finest film from between them. Any one may convince himself of this by placing a little upon a perfectly clean and dry oil-stone, and then rubbing up the face of a broad chisel upon it. The sensation of the bite (I know of no other word to express it) is very curious, and renders any further explanation unnecessary; it seems as if the stone and the steel had absolutely nothing between them, or even as if they were positively brought together by some attractive force. I have applied this property of carbolic acid, with great apparent advantage, to the

following operations:—Grinding, filing, boring, and sawing in metal. When dissolved in fifteen parts by measure of methylated alcohol, it forms a milk-white emulsion if poured into water, and it may be worth while to ascertain whether such carbolated water would facilitate the ordinary work of the grindstone, a point on which I am not able to speak with certainty. If any of your readers should experience, as I did, much difficulty in obtaining the crude carbolic acid, I shall have much pleasure in indicating the source from whence mine was derived, or in supplying any practical engineer with a small sample so long as my little quantity holds out.

JOHN EYRE ASHBY, LL. D.

Enfield, Middlesex, July 7th.

Enormous Increase of the English Glass Manufacture.

From Herapath's Railway Journal, No. 1204.

A very beautiful model, and quite unique in its way as instancing the rapid advances made in the manufacture of glass of late years, has just been placed in the galleries of the Crystal Palace at Sydenham. By this model, visitors may see the great extent of Messrs. Hartley's works—who, by the way, were the contractors for the glass used by the Messrs. Kelk and Lucas at the International Exhibition—and the different descriptions of glass manufactured. These consist of crown, sheet, patent rough plate for roofing, colored for artists, &c., and the processes of flattening, blowing, warehousing, annealing, and packing are exemplified. The model occupies a space of about 22 feet by 9, and is crowded by the various chimneys and building necessary to a giant manufactory. In the National Exhibition, which it must be remembered is mainly a brick structure, there have been used about 600,000 superficial feet of glass, weighing about 300 tons, and on each of the domes is 30 tons of glass! It is scarcely credible that 30 years ago there was not a foot of sheet glass made in this country. About that time foreign workmen were brought over by Mr. Hartley, but the manufacture languished for several years, and did not fairly take root in English soil until the repeal of the excise duties in 1845. Yet what is the state of this industry now in which we are exporting it very largely to all parts of the world? We are informed that the yearly production of sheet glass in England at the present time is equivalent to fifty millions of superficial feet of glass weighing 1 lb. to the foot, or more than sufficient to encircle the globe with a band 12 ins. wide. One glass-house pot will produce about 150,000 to 160,000 feet per annum, and each furnace contains eight of these pots. Hence, each furnace is capable of producing a million and a quarter of superficial feet a year; and as Messrs. Hartley show ten glass-houses on their model, they could, if all produced the same glass as they supplied to Messrs. Kelk and Lucas, turn out 12,500,000 superficial feet per annum, or a foot per head for all the male population of the United Kingdom.—*Globe.*

For the Journal of the Franklin Institute.

Application of J. G. ABBOTT and A. LAWRENCE, *in interference with the Patent of James Spear, of March* 22, 1859, *for an Improvement in Stoves.* Reported by H. HOWSON, Esq., Philadelphia.

U. S. Patent Office, August 6, 1859.

Honorable Commissioner of Patents:

SIR:—The invention which is the subject of contest in this case, is thus claimed by Mr. Spear in the patent which has been granted him, viz., "The combination of the slide E, in the door frame F, with the ring M and the cylinder B, and the body of the stove A, as constructed in the manner and for the purpose set forth."

In the application of Abbott & Lawrence, the claim is thus enunciated: "The combination of the ring R, perforated door frame F, extending down over the ring, and the slide B, with the stove cylinder as set forth." (The amendment by which it is proposed to claim the equivalent of the slide B, it will thus be observed, has not been regarded, it being of doubtful propriety to allow a change of claim after interference declared.)

An inspection of the drawings, in connexion with the above claims, shows with slight variation in construction, an identity of invention, the same being a certain combination of features for the purpose of producing a gas burning stove, that denomination being understood to apply to stoves in which provision is made for igniting the carbon of the products of combustion, by introducing thereto jets of heated air immediately over the fuel, at the top of the fire pot.

Allowing the invention on the part of the patentee to date as early as the first or second week of August, 1858, when, according to the testimony of Walter, Spear told him to make slides to Kisterbock's (or Silver's) stove, "to put one on the frame of the door and under the door to connect with a ring," &c., whether an earlier date can be shown by the applicants, will depend upon the disposition which is to be made of the position insisted upon on the part of the patentee; that the testimony in chief on the part of the applicants must be regarded as having closed with Sailor and Smith, subsequent to which, nothing but rebutting testimony was properly admissible.

It is believed, however, that the enforcement of a rule so purely technical, would not be consistent with those limited powers with which the Office is clothed by the law in cases of this kind, nor with what is known to be official practice.

The Office having no compulsory power for the production of testimony, is obliged to decide disputes as to points of priority upon such evidence as can be obtained through the voluntary attendance of witnesses. All the testimony desired in any particular case, can therefore seldom be produced at once; and although this circumstance is an unsatisfactory one as regards the complete reliability of testimony so procured, it is believed that a still greater evil to the cause of justice would result from excluding it.

This view is sustained by the decision, referred to in his argument by the Counsel for applicants, of Commissioner Mason, in the interference case of Schlough *vs.* Vansycle.

What then is the effect of the evidence, if admitted? It had been proven by Sailor, a designer and carver, that he had about the 1st of December, 1858, made the design for a door, which appears as Exhibit 1; on showing which to the firm, he was ordered to leave some holes at the lower side of the door frame, for the purpose of some kind of register. Smith also had testified that the firm to which he belonged had been applied to the first week in November, 1858, to make several sizes of stove involving the invention in dispute, and confirms Sailor as to the time when drawing Exhibit 1 was completed.

Now these witnesses were parties who were not engaged directly in the establishment of Abbott & Lawrence; and it is not perceived, therefore, that there is irreconcilable inconsistency of the subsequent witnesses, Lawrence and Bell, in alleging an earlier knowledge obtained by them respectively as directly employed in the service of Abbott & Lawrence.

It is true, that the witnesses do not agree precisely as to the time when the invention was made by the applicants; but the difference in this respect is perhaps explained by the different situation of the witnesses in relation to the business of the establishment. It does not appear improbable that Lawrence, as the foreman of the establishment, should have possessed a knowledge of the invention by Abbott & Lawrence earlier than could be had by Nicholson, the salesman, or by the designer and pattern maker of a different establishment.

The testimony of Lawrence and Bell fixes the invention on the part of the applicants as far back as 1857, and if the invention can be regarded as complete at that time, the question is decided.

It is indeed to be regretted that the sketches of the invention, which are said by the witnesses, Lawrence, to have been made by both the applicants at the time just referred to, had not been produced, though they can scarcely be regarded as necessary to enable a mechanic to carry an invention into actual operation. It is the testimony of Lawrence and Bell that the stove for which the design, Exhibit 9, was patented September 8, 1857, was upon the same principle as that in question, the sole difference being that, whereas the air was introduced in the stove made under that patent through an aperture in the rear of the stove which connects with another in the ring, it was in June or July, 1857, determined to introduce it through a hole in the *lower part of the door*, the door being also provided with a slide or valve. The slight change which constitutes the invention was thus intelligible from mere description, and must doubtless be deemed a sufficient compliance with the requirements of the Office in that regard. See rules and directions, section 7.

The time which intervenes between the invention and its adoption in practice, appears also of somewhat unreasonable length; yet we regard it as less so when informed that the delay is in part owing to objections of mechanical difficulty and expense in applying it, and to

a desire to avoid interfering with the sales of valuable stock on hand constructed after the pattern, Exhibit 9.

Upon the whole, I am led to the conclusion that Messrs. Abbott & Lawrence appear from the evidence, to have been the prior inventors of the combination of devices constituting the subject of dispute in this interference, and so report.

All of which is respectfully submitted,

ROBERT D. CLARK,
Examiner in Charge.

The foregoing report is confirmed, adjudging priority of invention to Abbott & Lawrence, to whom a patent is ordered to issue. Limit of appeal thirty days.

S. T. SHUGERT,
Acting Commissioner.

Aug. 8, 1859.

JAS. SPEAR, Appellant, *vs.* J. G. ABBOTT & A. LAWRENCE, Appellees.

On appeal from the decision of the Commissioner of Patents of the 8th of August, 1859, awarding to appellees a patent as prior inventors of a certain combination of features, to produce gas burning stoves.

The specifications and claims of the parties litigant in this case, with the drawings filed in the office, show the inventions claimed by appellant and appellees, to be substantially the same, and the question to be decided *is* who was the prior inventor?

If the testimony of Bell and Lawrence was legally taken, and properly before the Commissioner, and before me on appeal, there can be no doubt the appellees have established their priority as inventors.

It has accordingly been earnestly maintained by the counsel for Spear, that the depositions of these witnesses must be excluded. He invokes the protection of the rule of practice in the courts of England and this country, in the trial of common law causes before a jury, which requires a party to examine all his witnesses in chief before he closes his opening examination, and forbids afterwards the introduction of any other than *rebutting* proof.

This rule in jury trials, produces order and method, and expedition in the transaction of business, and promotes fairness and prevents fraud in the conduct of common law causes. It makes a party *show* his *hand* to his adversary, prevents his splitting up his proof and retaining part for reply, and defeats the fraudulent purpose, if such exists, to make evidence to overcome and fit the defence. But the rule has no application in equity, or admiralty, or in any other than a common law tribunal in jury causes.

The proceedings in the Patent Office in contested cases, have no resemblance to trials at law. The testimony is not taken before the Commissioner of Patents at the place of trial, but as in equity, before a commissioner, at the place of residence of the witnesses, without any compulsory power in the Patent Office, to coerce their attendance, and who may be scattered over the country at remote and distant points from each other. The Commissioner in the first instance, and the

Judge on appeal, decides both law and fact, without the intervention of a jury.

Besides, by the 12th section of the Act of Congress of the 3d March, 1839, the power to make regulations for the taking of testimony in contested cases in the Patent Office, is expressly conferred on the Commissioner, not subject to any control or revision by the appellate judge.

In virtue of this power, the following regulations have been adopted: 41st Rule, "upon the declaration of an interference, a day will be fixed for closing the testimony, and a further day fixed for the hearing of the cause. Previous to this latter day, the arguments of counsel must be filed, if at all." 86th Rule. "That before the deposition of a witness or witnesses be taken, by either party, reasonable notice shall be given to the opposite party of the time and place, when and where such deposition or depositions will be taken, so that the opposite party may cross-examine, &c., and such notice shall, with proof of service of the same, be attached to the deposition or depositions, whether the party cross-examine or not, and such notice shall be given in sufficient time for the appearance of the opposite party, and for the transmission of the evidence to the Patent Office before the day of hearing."

These Rules of the Commissioner, made under the authority of the Act of Congress to which I have referred, give to either of the litigating parties the right to take depositions without restraint, up to the day of hearing fixed by the Office, or to a day near enough to give time for the transmission of the evidence to the Patent Office. While these rules are in existence the parties are bound by them, and the judge on appeal must give effect to them, and as the disputed depositions of Bell and Lawrence, have been taken in conformity with the rules, they are properly and legally in the case.

I add that the decision and practice of the Office are in harmony with these rules, and the appellees had a right to rely upon them.

If the rules are abused, and work wrong, which I do not mean to say, the Commissioner has power to alter them, but such alteration could only operate prospectively.

These witnesses last referred to are not impeached, and they prove priority of invention for the appellees. It is argued that they contradict and falsify Sailor and Smith, the former witnesses of appellees, which appellees cannot lawfully do, as it is against law for a party to discredit his own witness, but this is not so. There is no contradiction, no necessary conflict. Sailor and Smith may have truly stated the time when the invention first came to their knowledge, and the other witnesses may have testified also truly to earlier dates, within their knowledge. As the appellees made their application to the office for a patent within two years after perfecting their invention, and reducing it to practice, I think the Commissioner properly awarded them a patent, and I do, this 21st September, 1859, affirm the judgment of the Commissioner of date the eighth day of August, 1859.

I herewith return all the papers and models to the Office with this my opinion and judgment, this 21st September, 1859.

JAS. DUNLOP, *Ch. Judge.*

To the Hon. WM. D. BISHOP,
Commissioner of Patents, Washington.

FRANKLIN INSTITUTE.

Proceedings of the Stated Monthly Meeting, Sept. 18, 1862.

J. C. Cresson, President, in the chair.
John Agnew, Vice President,
Isaac B. Garrigues, Recording Secretary, } Present.

The minutes of the last meeting were read and approved.

Letters were read from M. Cesar Daley, Paris, France; the Literary and Philosophical Society, Liverpool, England; and Frederick Emmerick, Esq., Washington, D. C.

Donations to the Library were received from the Royal Astronomical Society, London, and the Literary and Philosophical Society, Liverpool, England; Capt. Wm. H. Swift, Boston; the State Lunatic Asylum, Utica, New York; Thomas C. Clark, Esq., Camden, New Jersey; Frederick Emmerick, Esq., Washington, D. C.; and James J. Barclay, Esq., Prof. John F. Frazer, and Prof. John C. Cresson, Philadelphia.

The Periodicals received in exchange for the Journal of the Institute, were laid on the table.

The Treasurer's statement of the receipts and payments for the month of August was read.

The Board of Managers and Standing Committees reported their minutes.

Candidates for membership in the Institute (2) were proposed, and the candidates (3) proposed at the last meeting were duly elected.

The President gave an account of the rain storm of Sept. 12th inst., in which the quantity of rain at some points was larger than any on record in the vicinity of Philadelphia. The area over which the excessive rain fell appears to have been small, very little of it being out of the corporate limits of the city; and the only streams much swollen by it were those which reach the Delaware and Schuylkill Rivers within these limits. Measurements of the quantity of rain made at several stations of the City Gas Works, showed a remarkable difference in its amount at places but a few miles apart. At the First Ward station, on the Schuylkill below Gray's Ferry, the quantity was $3\frac{6}{10}$ths inches; at the Fifteenth Ward station, on the Schuylkill near Fairmount, it was 6 inches; and at the Twentieth Ward station, on the Cohocksink Creek, near Ninth and Diamond Streets, it was 9 inches. These three stations are located at the angles of an obtuse triangle,

whose long side connecting the First and Twentieth Wards, is about 6 miles long in a direction nearly S. W. and N. E., and the two short sides 3½ miles each. This great amount of rain fell in the course of less than five hours, between 6 and 11 A. M., and necessarily produced a great freshet in the water-courses of the district lying between the Tacony on the north and the Cohocksink on the south. Both these, as well as Frankford Creek, the Wingohocking, Threemile Run, and Gunner's Run, were out of their banks, inundating all the adjacent low grounds, and sweeping away substantial stone bridges that have withstood the storms of half a century.

Some of these bridges were examined for the purpose of learning how their destruction was brought about, and two of them appear to have been destroyed in a way nearly identical, resulting from a very unusual peculiarity in their water-way. At Broad Street an embankment has been raised across the valley through which the Cohocksink flows, reaching from bank to bank, a distance of more than 500 feet. The height of this embankment is about 25 feet above the bed of the creek, and its width on top about 120 feet, with short retaining walls on each side of the brick arch for the water-way.

This archway is a semicircle of 12 feet radius, standing on perpendicular abutments that rise about five feet above the ordinary water level, giving a passage of 24 feet width and 17 feet clear height.

This large culvert does not extend entirely through the embankment, but stops short of the eastern or outlet side about 12 or 15 feet, where it is abruptly terminated against the end of a small semicircular arch of only 8 feet span and 6 feet height above water level, which affords only one-ninth as much water-way.

The bridge next west of this, distant about 300 yards, is on the Lamb Tavern road; it is of ancient construction, of good stone masonry, with a semicircular water-way of 20 feet span and 10 feet rise. The embankment that crosses the valley is about 200 feet long, supported throughout by stone retaining walls, on which the parapet rises 2 feet above the macadamized roadway, or 18 feet above the bed of the stream; the width of embankment from out to out of retaining walls is 35 feet.

The outlet end of the water-way under this bridge has recently been closed by a connexion with an 8-feet culvert, which extends across the intervening flat nearly to Broad Street.

This brief description of these structures leaves but little room for doubt as to the manner of their demolition.

An accumulation of water behind a small bridge on Islington lane, a short distance westward, overthrew that bridge, and came down in a large wave upon the Lamb Tavern bridge, which was already passing as much water as the culvert that closed its outlet could vent, and the sudden impact of this great mass burst upward the overcharged archway and mounted the parapet walls, carrying away the latter, and tearing out the obstructing culvert for a hundred feet of its length.

The lake formed above the bridge now obtained free vent, and this double flood rushed across the intervening flat to the Broad Street

embankment, where the waters were already struggling for passage through the small outlet of the large archway—the upper portion of the latter being several feet above the level of the torrent. The momentum of the great wave caused it to rise in the large arch so as to fill momentarily its entire cross section, and compress the imprisoned air sufficiently to blow up its eastern extremity for a length of about 40 feet, while the western portion still stood.

The part thus broken up fell into the chasm, and was immediately swept by the torrent into the adjacent meadow.

In one case the archway was completely filled with water before the advent of the great wave, and the inlet end was destroyed, leaving the outlet end whole; in the other the archway contained air along its crown, which was forced to the furthest extremity of the large cavity, and there did its work of destruction.

At Tenth Street, the fresh embankment on which the street was graded became soft by the superincumbent waters which the 9-feet culvert was unable to vent, and when it was pressed by the rush from the breakages above, it gave way, and allowed the triple lake to rush through and add their impetus to a fourth pool, which had already accumulated in the low ground between Tenth and Seventh Streets, south of Diamond Street.

We can form an idea of the immense mass of water thus accumulated and driven through the narrow streets east of Seventh Street, when we consider that torrents of rain falling in less than five hours to a depth of nearly 9 inches over an area of about 2 square miles, had their only outlet in this direction.

The sudden irruptive wave was the produce of four distinct pools within 1½ miles distance, pouring out their waters almost simultaneously into a low district, already inundated by its own share of the great rain.

Mr. Burson exhibited one of his Grain Binders, and explained its action. It consists of a stand carrying a jointed curved arm, attached to a lever worked by the attendant. A shaft passes down the centre of the stand, from top to bottom, and has at its upper end a crank handle, and at its lower end a set of bevel gear wheels, which open and close a pair of nippers, a pair of jaws, and then give the latter several revolutions. A spool of wood is attached near the top of the stand, upon which is wound No. 24 annealed iron wire. This wire passes through grooved pulleys, placed on the jointed curved arm along its length and at its extremity. The movement of this arm brings its point close up to the nippers. The binder is attached to the platform of a Manny Reaper in such a way that the arm in its sweep grasps the stalks as they fall upon the platform; its point passing along a groove cut below the surface, causes all the stalks within its reach to be gathered up tightly, when the point brings the wire between the nippers and jaws; a single rotation is then given by the attendant to the crank handle, which cuts off the wire, gives the ends

several twists, releases them, and seizes the end of the wire again. The attendant then raises the arm by moving a lever, whilst the wire runs off the spool, and is held high enough to permit the stalks to fall beneath it, ready for the next sheaf. Its total weight is about 100 pounds; one person can attend it, and, it is said, bind as fast as the reaper can cut. Several certificates, given by farmers in New Jersey and Illinois, and the Secretary of the Wisconsin Agricultural Society, bear witness to its efficiency.

Chief Engineer, W. W. W. Wood, U. S. Navy, being present, was requested to state to the meeting the cause of the return to this port of the iron clad frigate, *New Ironsides*, several statements having appeared setting forth various causes for the return of that vessel, (Mr. Wood having been connected with the construction of this ship, and having been on board during her recent experimental cruise by order of the Navy Department.)

Chief Engineer Wood, after stating the reasons which caused her return, (*which was for the purpose of having her spars again put on board,*) and the very satisfactory performance of the ship, proceeded to give an interesting statement of the formidable arrangements and heavy armament on board, and also the history and causes which have led to the introduction of these immense guns.

Mr. Wood proceeded to give the theories incident, and the difficulties practically encountered in the fabrication of heavy ordnance. It was found that guns made of a highly elastic iron were capable of greater endurance, than if a more compact iron of greater tensile strength per sectional inch of area had been used; he had been connected with a series of experiments wherein it was demonstrated by practical tests, that heavy pieces of ordnance, the iron of which was capable of withstanding from 39,000 to 40,000 pounds tensile strength per sectional inch of area, with a corresponding density, was not capable of the endurance of similar pieces, the specimens of iron from which sustained a tensile strength of not more than from 17,000 to 23,000 pounds per inch of area, having of course a much less specific gravity or density. In the latter case one piece sustained in addition to the proof charge, over 1700 service charges with no perceptible alteration, except an enlargement of the vent after about 900 fires, and slightly furrowed indentations in the chamber leading to the vent. He next proceeded to state the theories and means practically introduced to produce guns of the greatest strength to withstand charges of maximum effect.

The general accepted theory as to the causes of the breaking of heavy pieces, was that, in the ordinary method of casting them, the iron cooling on the exterior portions of the gun soonest, produced, as a matter of course, a strain, by unequal shrinkage in the mass. Various methods have been resorted to to prevent this effect, such as casting the piece hollow and cooling from the interior while the mould was heated on the outside to prevent too rapid cooling of the exterior,

and to equalize the temperature during the process throughout the mass of iron composing the casting as much as possible, so as to prevent any strain which would be caused by unequal cooling, the process being that of Captain Rodman of the U. S. Army. On the other hand the Dahlgren guns are, in some cases, cast in form more nearly approaching a cylinder, the additional metal on the exterior causing strain by unequal shrinkage in having first cooled in the mould, being removed in finishing the gun, which has been cast solid, and what is supposed to be the weakest part of the mass of iron *bored out* and removed.

These difficulties it will be appreciated, increase as the mass of the casting becomes enlarged in the fabrication of great guns. "All the 13-inch mortars used by the English in the bombardment of Sweaborg during the last war with Russia, burst after an average of 120 rounds, having split in two equal halves in a plane passing through the axis of the vent, exhibiting no defect except just at the bottom of the chamber, where a small irregular cavity was found with ragged sides and bottom, as though burrowed into by some corroding agent."

Mr. Wood also alluded to the age of the gun with respect to its powers of endurance, wherein it was found by experiment that the age of the gun exerted a very great influence upon its endurance; he explained by the supposition, that the unequal shrinkage which has to some extent unavoidably taken place in the cooling of the gun when cast is compensated for by the re-arrangement of the atoms of crystallization by the law of cohesion in their proper direction.

Chief Engineer Wood concluded his remarks on this very interesting subject by briefly stating what he believed to be a great cause of the failure of these heavy pieces of ordnance, which was on the principle of unequal expansion between the interior and exterior portions of the pieces when being rapidly fired; the interior of the gun being first and constantly heated, before the conducting properties of the iron have conveyed a corresponding temperature to the exterior. We have a strain upon the piece equal to the difference of expansion, or that due to the difference of elongation of masses of iron at unequal temperatures, by which it is seen that the normal condition of the crystals of iron are disturbed in proportion to the spaces occupied in respect to each other in solid mass, in proof of which he cited the circumstances of the explosion of the gun on board the *Naugatuck*, and the fractures which take place in the breaking of these large pieces of ordnance.

Mr. Wood promises a continuation of this subject, illustrating the views expressed, on a future occasion.

Mr. John W. Nystrom remarked—To cast a gun solid and 8 ins. larger in diameter, to be turned off in finishing it, I believe is very injurious to the strength of the same; not only because the best or strongest part of the metal at the surface is turned away, but the strain caused by different shrinkage in cooling is thereby partly relieved, and causes as it were a crushing process in the metal of the

finished gun. I have made experiments in Russia with cast iron bars of one inch square, and about two feet long; one bar was cast the correct size, and one cast two inches square and planed off ½ inch on each side to one inch square. The lateral strength of the bars was carefully experimented upon, and the bar cast the correct size was found to be much stronger than the planed one. I have forgotten the relative strength of the bars, but think it was somewhere about 25 per cent. in favor of the 1-inch cast bar. I consider the subject of sufficient importance to repeat the experiment, and hope to be able to give a correct account of the same at a future meeting. In Russia I have made rollers for rolling angle iron, ships' frames, keel gutters, and other irregular forms, which rollers were cast so correct that when centred in a lathe there was but a trifle to do with the tool. The mould was turned in the flask with an iron sweep of the correct shape of the roller, and no allowance made for turning or finishing the same.

Since my return to this country I have seen rollers moulded in a similar manner by wooden sweeps at Phœnixville, Penna., where about ⅜ths of an inch was allowed for turning or finishing, just enough to take away the most valuable part of the roller. The mould should not only be formed by an iron sweep, but the blacking and finishing of the same ought to be accomplished by the same instrument, when the turning of the roller would become a mere grinding process with sandstone or emery, and the most valuable part of the metal would be retained for service. This is the principle upon which I would propose to mould and cast large guns, and I believe it could be cast so perfect, even with rifles, that it could be taken direct from the foundry into service. The cooling process of large guns is of equal importance to the form and selection of iron for the same. The Rodman process of cooling the gun from the core I would employ as a hardening or chilling process, and cool the gun similar to the Whitney car-wheel annealing process, for a time of say one day for each inch of the calibre of the gun, or an 11-inch gun to be cooling 11 days, the time necessary for the atoms of iron to comfortably locate themselves in relation to one another. When the gun is cooled down to about 400° Fahr., it should be taken up, the muzzle closed with a wooden plug, to prevent circulation of air conducting heat from the bore, and the outside of the gun be evenly washed with or dipped into water, being careful that no water gets into the bore and cool it down to the temperature of the atmosphere. The object of this last cooling operation is to give the metal in the bore a slight tensile strain, while that on the outer surface would be slightly compressed; then when the gun becomes hot by firing, there would be the least strain in the metal by shrinkage, and would constitute the strongest possible gun. Formerly, cast iron guns were seldom turned, but cast finished on the outside, though sufficient care has not been taken in moulding them.

A Comparison of some of the Meteorological Phenomena of AUGUST, 1862, *with those of* AUGUST, 1861, *and of the same month for* TWELVE *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 10½′ W. from Greenwich. By JAMES A. KIRKPATRICK, A.M.

	August, 1862.	August, 1861.	August, 12 Years.
Thermometer—Highest degree,	95·0°	91°	97·0°
" " date,	8th	5th	2 '56; 4 '59
" Warmest day—Mean,	87·67	85·2	87·67
" " " date,	9th	5th	9th, 1862
" Lowest degree,	51·0	51·5	47·0
" " date,	25th	14th	26th, 1856
" Coldest day—Mean,	66·17	62·5	59·0
" " " date,	24th and 30th	13th	26th, 1856
" Mean daily oscillation,	16·56	16·84	16·07
" " " range,	3·89	3·94	3·79
" Means at 7 A. M.,	71·47	68·88	70·27
" " 2 P. M.,	82·93	79·52	80·82
" " 9 P. M.,	75·13	74·05	73·33
" " for the Month,	76·51	73·15	74·81
Barometer—Highest—Inches,	30·099 in.	30·212 in.	30·255 in.
" " date,	24th	21st	20th, 1855
" Greatest daily mean press.,	30·066	30·160	30·229
" " date,	24th	21st	20 & 31, 1855
" Lowest—Inches,	29·557	29·608	29·356
" " date,	9th	13th	20th 1856
" Least daily mean pressure,	29·588	29·661	29·388
" " date,	9th	10th	20th 1856
" Mean daily range,	·122	·098	·095
" Means at 7 A. M.,	29·829	29·9 2	29·878
" " 2 P. M.,	29·796	29·896	29·850
" " 9 P. M.,	29·818	29·910	29·868
" " for the Month,	29·814	29·906	29·865
Force of Vapor—Greatest—Inches,	·939 in.	·841 in.	1·024 in.
" " " date,	8th	5th	1st 1854
" " Least—Inches,	·290	·296	·268
" " " date,	30th	15th	26 '56; 29 '59
" " Means at 7 A. M.,	·562	·602	·584
" " " 2 P. M.,	·524	·608	·591
" " " 9 P. M.,	·586	·612	·611
" " " for the month,	·557	·607	·595
Relative Humidity—Greatest per cent.,	87· per ct.	92· per ct.	100· per ct.
" " " date,	31st	29th	26th 1854
" " Least per cent,	30·	34.	27·
" " " date,	2d	15th	1st, 1860
" " Means at 7 A. M.,	70·5	83·4	76·8
" " " 2 P. M.,	45·6	60·3	55·8
" " " 9 P. M.,	65·4	79·3	73·4
" " " for the month,	60·5	74·3	68·7
Clouds—Number of Clear days,*	10	7	10
" " Cloudy days,	21	24	21
" Means of sky cov'd at 7 A. M.,	47·4 per ct.	69·7 per ct.	54·5 per ct.
" " " " 2 P. M.,	58·7	63·9	59 6
" " " " 9 P. M.,	37·7	50·0	41 6
" " " for the month,	47·9	61·2	51·9
Rain—Amount in inches,	1·455 in.	2·864 in.	4·289 in.
Number of days on which Rain fell,	7·	12·	10·1
Prevailing Winds,	s. 90° w. ·117	s 85°55′ E ·088	s 83°28′ w·088

* Less than one-third covered at the hours of observation.